COMPARISON DATA FOR MODEL TO PROTOTYPE AGREEMENT

For:

The US Army Corps of Engineers:

Mississippi Valley Division

Memphis District

St. Louis District

Engineer Research and Development Center

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August 2003

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

TABLE Page

1. ANALYSIS OF MOVABLE BED MODEL AND PROTOTYPE DATA

1.1. Introduction

The evaluation of micromodel techniques raises the question of how well the respective models reproduced prototype trends. Although the primary question is whether the micromodel can predict prototype response in a calibrated model, about all that can be done is to investigate the ability of the models to reproduce existing, or base, conditions.

Micromodel use also relies upon knowledge gained from previous movable bed model work, most noteably by the Engineering Research and Development Center (ERDC, formerly the Waterways Experiment Station or WES). For this reason, comparitive data for sixteen

This document contains comparitive data for thirty previously completed movable bed model studies. Appendix A contains a case study that details methodology used in developing the comparison data.

1.2. Comparison Concept (what parameters to compare?)

Movable bed physical model studies recorded in the literature provided little detail regarding assessment of model and prototype agreement. Most reported a qualitative comparison of cross-sectional area or shape as the primary means for verifying model-to-prototype agreement. This qualitative comparison generally consisted of a visual comparison of model and prototype bathymetric contours and, on occasion, plots of reference cross-sections with model data superpositioned over prototype data. Even the detailed descriptions of model procedures in USBR (1980) and more particularly Franco (1978) yielded little detail of the exact methodology used to assess model verification with the prototype.

Review of various report drawings indicated that model and prototype bathymetric contour maps were shaded (e.g., color coded) to facilitate ready visual comparisons. This technique is virtually the same as utilized by the micromodel approach described by Davinroy (1994) and in Gaines (1999). Based on published literature, on discussions with various modelers and on previous experience, the real comparisons of whether a model was considered calibrated/verified depended on a visual interpretation of model and prototype bathymetry by the respective modeler(s) as opposed to any rigorous technique.

Variables describing the channel morphology seemed most useful for assessment model to prototype agreement (Rosgen, 1996, and Leopold, et al. 1964). A principle morphologic variable, discharge, was not included in the present investigation because discharge data were largely unavailability for the model studies (neither prototype nor model discharge data were available for the small-scale models). Additionally, the sinuosity was represented by thalweg position in each cross-section as referenced to a common point on the section. Cross-section area, width, depth and width/depth ratio describe the hydraulic geometry and offer insight into the two-dimensional character of the flow. The morphologic parameters selected for developing comparison data were:

1. Thalweg position within the active channel (as a surrogate for sinuosity),
2. Cross-section area,
3. Channel width,
4. Hydraulic depth, and
5. Width/depth ratio (from cross-section width and hydraulic depth).

Direct calculation of thalweg length for each model case provided little contribution toward evaluating morphological similarity on a cross-sectional basis. Therefore, a slightly different use of thalweg sinuosity was considered in the present research. Position of the thalweg laterally across the cross-section was adopted to address agreement between prototype and model sinuosity. Exact reproduction of the thalweg position occured when the distance between a common reference point for the cross-section (e.g., referenced to the left descending bank) and the thalweg for both model and prototype were the same. Variation in thalweg position between two bathymetric surveys was expressed through a relative comparison of the respective thalweg positional lengths (between the thalweg and the reference baseline) for each survey.

Analysis of channel morphology also utilized channel width and depth to describe the hydraulic geometry of a Range. Channel width described the horizontal linear distance between points on the left and right banks of the stream at a common elevation. Width influenced the lateral distribution of flow and sediment across the channel and provided some indication of the type of flow (e.g., 2-dimensional or 3-dimensional patterns) anticipated in the reach. The cross-section depth for the current investigation was represented by the hydraulic depth (area divided by top width). Hydraulic depth (H) provided an indication of channel depth and influenced both the relative roughness and the vertical distribution of velocity. The ratio of width to hydraulic depth, W/H, is considered to be a crutial morphologic variable that describe the channel geometry. The width/depth ratio aids in determining the two-dimensional character of flow patterns.

Channel cross-sectional area values were a function of water surface elevation used in the area computation. Initial comparison work considered the use of area versus elevation curves to assess prototype and model variability. While the area-elevation data provided insight into variable sensitivity, this approach resulted in a large volume of data that produced no useful summary relationships. The data contributed little toward understanding overall model-to-prototype agreement. The cross-sectional area-elevation approach was subsequently modified to limit calculations to specific key elevations. The key elevations were selected to coincide with elevations typically associated with defining actual prototype conditions and with assessing a model's ability to reproduce prototype conditions during model calibration. Channel width and hydraulic depth at these key elevations provided an additional means to evaluate cross-section shape.

2. COMPARISONS

2.1. Methodology

Elevations in all models analyzed were based on an arbitrary reference plane that was developed to support maintenance of navigation on the subject rivers. The prototype reference plane equated a zero elevation with the most likely minimum water level anticipated on the specific river reach. An example of this reference plane was the Low Water Reference Plan (LWRP) used for the Mississippi River. The Mississippi River LWRP corresponded to the water surface elevation equaled or exceeded 97 percent of the time. Therefore, bottom elevations reported in terms of LWRP elevation indicated navigable depths below an expected low water level. The advantage of using such a reference plane manifested itself through a ready discernment of areas with inadequate navigation depths, thus aiding maintenance activities. The reference elevation selected for the present comparisons was the zero elevation of this reference plane. This elevation represented a focal elevation for the various model studies considered and therefore provided useful indications of model-to-prototype bathymetry agreement. An LWRP elevation of +30 represents a typical bankfull prototype stage.

Evaluating variability between various bathymetric surfaces was accomplished by considering five particular cross-sectional characteristics determined for both model and prototype surveys. Each of these characteristics described a particular morphological or hydraulic aspect of the bathymetry being analyzed. Selected characteristics included cross-sectional area at 0.0 LWRP (A_0), channel width at 0.0 LWRP (W_0), hydraulic depth at 0.0 LWRP, (H_0), and the thalweg position (TP). Thalweg position was referenced to the left descending bank as depicted in Figure 2-1.

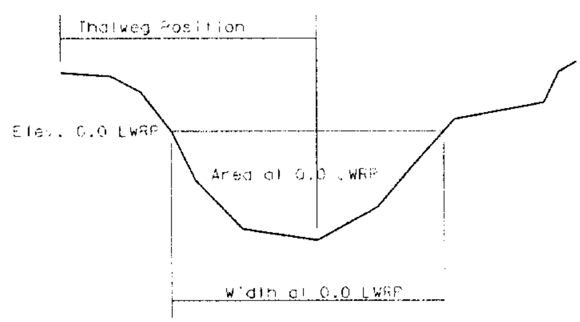

Figure 2-1 Cross-section Parameter Locations (Flow is into Page).

2.2. Model Selection.

Criteria used for determining if a model study could be included in the present analysis were simple. Inclusion of a model required that at least one prototype hydrographic survey was used to calibrate the model and that both calibrated model bathymetry and all prototype bathymetry used in model calibration were available either in hard copy map, tabular coordinate listing, or digital terrain model form. Regardless of these simple requirements, very few model studies outside the US Army Corps of Engineers were found to have the requisite information. A data call to the engineering public at large (Gaines and Maynord, 2001) resulted in no new information to supplement the present study.

Relatively few model studies were included in the present research; however, the thirty models analyzed provided a sufficiently large data set to gain an understanding of model/prototype agreement at calibration. Models were grouped into two categories, large-scale models (horizontal scale less than 1:600) and small-scale models (horizontal scale greater than 1:3600). Appendix A presents a case study example of each type of model (e.g., large-scale and small-scale). The case study includes details of the project along with pictures, maps, and data for both the models and prototype river reach. No attempt was made to differentiate between the type of models (crushed coal, sand, or plastic bed material) or operational constraints such as time and/or data limitations. Rather, models were grouped in a manner that best facilitated analysis.

Sixteen large-scale physical models were identified for inclusion in the present study. Horizontal scales of these models ranged from 72:1 to 600:1 with vertical distortion ranging from 1.0 to 10. Large-scale model studies included in the present investigation are shown in Table 2-1. Appendix B provides general descriptions of these models. Most of these model studies were completed prior to 1990 at the ERDC. Model data were available through report plates depicting both model and prototype bathymetry.

Fourteen micromodels were also identified for inclusion in the present study. These models had horizontal scales ranging from 3,600:1 to 20,000:1 with vertical distortions ranging from 6 to 20. Small-scale model studies included in the present investigation are shown in Table 2-2. Appendix C provides general descriptions of these models. Models were completed primarily by the St. Louis District Corps of Engineers Applied River Engineering Center, with two models completed by the Memphis District Corps of Engineers Applied River Engineering Center.

Two micromodels completed by the Memphis District specifically targeted scale studies for the present investigation. These models of the Kate Aubrey reach of the Mississippi River were designed with horizontal scales of 1:16,000 and 1:8,000 (one was exactly twice the size of the other in the horizontal dimension). Selection of these horizontal scales resulted from consideration of scales previously used in micromodels of the Mississippi River. The smaller Kate Aubrey micromodel, 1:16,000, was near the lower extreme of micromodel scale while the larger micromodel, 1:8,000, was near the upper extreme of micromodel scale. Both of the Kate-Aubrey micromodels were also used to assess the predictive capability of the micromodel technique. To evaluate the predictive capability of the micromodel, the models were calibrated to a mid-1970's condition in the prototype. The models were then adjusted by modifying and adding structures to reflect a future prototype condition, 1998. The second, future condition in the model was then compared to the observed 1998 prototype surveys as the basis of comparison.

Table 2-1 Previous Large-Scale Model Investigations

Name (River)	Prototype Data Used in Model Verification	Horizontal Scale[a]	Distortion (Horiz:Vert.)
Baleshed-Ajax Bar (Mississippi)	1967, 1968	600:1	10:1
Blountstown (Apalachicola)	1977, 1978	120:1	1.5:1
Buck Island (Mississippi)	1976, 1977, 1978, 1979	300:1	3:1
Chipola Cutoff (Apalachicola)	1978, 1979	120:1	1.5:1
Devil's Island (Mississippi)	1973	400:1	4:1
Dogtooth Bend, (Mississippi)	1977, 1983	400:1	4:1
Kate Aubrey (Mississippi)	1975, 1976	300:1	3:1
Lake Dardanelle (Arkansas)	1971, 1973	120:1	1.5:1
Lock & Dam #2 (Red River)	1978, 1981	120:1	1.5:1
Lock and Dam #4 (Red River)	1978, 1981	120:1	1.5:1
Loosahatachie-Memphis (MS)	Jan 1986, Nov 1986	300:1	3:1
New Madrid Bar (Mississippi)	1976, 1977	480:1	8:1
Redeye Crossing (Mississippi)	1982, 1983	240:1	1.2:1
Smithland Locks & Dam (Ohio)	1983	150:1	1:1
West Access (Atchafalaya)	1989	120:1	1.5:1
Willamette River	1977, 1980	100:1	2:1

[a]Scale is prototype/model ratio.

Table 2-2 Previous Small-Scale Model Investigations

Name (River)	Prototype Data Used in Model Calibration	Horizontal Scale[a]	Distortion (Horz.: Vert.)
Mouth of White River (Mississippi)	1994, 1997	12000:1	10:1
Clarendon, AR (White)	1999	4200:1	14:1
Augusta, AR (White)	1999	3600:1	20:1
Vicksburg Front (Mississippi)	1994, 1997	14400:1	12:1
Wolf Island (Mississippi)	1997, 1998	7200:1	12:1
Memphis Harbor (Mississippi)	1996, 1997	4800:1	8:1
Lock & Dam 24 (Mississippi)	1993, 1995	9600:1	16:1
Savanna Bay (Mississippi)	1996	4800:1	8:1
Copeland Bend (Missouri)	1991, 1996	3600:1	15:1
Salt Lake (Mississippi)	1993, 1995, 1996, 1998	9600:1	16:1
Morgan City/Berwick Bay (Atchafalaya)	1999	7200:1	6:1
New Madrid (Mississippi)	1994	20000:1	16.7:1
Kate Aubrey (Mississippi)[1]	1973, 1975, 1976	16000:1	17.8:1
Kate Aubrey (Mississippi)[1]	1973, 1975, 1976	8000:1	13.3:1

[a]Scale is prototype/model ratio.

[1]Models conducted as part of present research for studying scale effects.

3. RESULTS

3.1. General

The thirty previous model study results were considered adequate for developing solutions to the particular problems under investigation. Therefore, these model studies help establish an acceptable standard for morphologic similarity requirements that can be associated with the types of problems and control measures investigated. These problems primarily consist of channel control measures implemented by the US Army Corps of Engineers.

Model to prototype agreement, or morphologic similarity, is quantified in this study using difference calculations and associated graphs and mean square error (MSE) values for each of the thirty previous model studies included in the analysis. Average difference and MSE values between individual data sets provide a quantitative expression of overall model/prototype agreement, but these values cannot be used alone in determining the quality of the modeling effort.

Based upon an analysis of the models included herein, the magnitude of differences, calculated for the five morphologic parameters in the micromodels, are similar to those calculated for the large-scale models. For example, differences in CROSS-SECTION AREA below 0.0 LWRP are –25 percent, -22 percent, and +13 for the Kate-Aubrey large-scale model, the 1:8000 micromodel and the 1:16000 micromodel, respectively. The MSE values for these models were 0.331, 0.216, 0.319, respectively.

Difference and MSE values for each model included in this study are shown in Tables 3-1, 3-2, 3-3, 3-4, and 3-5. Graphs of the average difference and MSE values provide a visual comparison the results obtained for each model (Figures 3-1, 3-2, 3-3, 3-4, and 3-5).

Table 3-1. Thalweg Comparisons for Thirty Previous Model Study Results

Large-Scale Model NAME	MODEL		Micromodel NAME	MODEL	
	DIFF	MSE		DIFF	MSE
Baleshed-Ajax	0.211	0.109	Augusta	-0.017	0.049
Blountstown	-0.074	0.031	Clarendon	0.035	0.032
Buck Island	-0.034	0.088	Copeland	0.029	0.002
Chipola Cutoff	0.278	0.247	KA 1:8000 Base	0.032	0.221
Devil's Island	-0.040	0.149	KA 1:8000 Predictive	0.071	0.064
Dogtooth Bend	-0.0474	0.0159	KA 1:16,000 Base	0.022	0.192
Kate-Aubrey	-0.270	0.224	KA 1:16000 Predictive	-0.006	0.091
Lake Dardanelle	0.404	0.470	Lock & Dam 24	0.003	0.023
Lock & Dam #2	-0.095	0.086	Memphis Harbor	0.023	0.051
Lock & Dam #4	-0.054	0.054	Morgan City	0.035	0.004
Loosahatchie-Memphis	-0.153	0.049	New Madrid	-0.031	0.027
New Madrid Bar	0.093	0.049	Salt Lake	-0.118	0.025
Redeye Crossing	0.013	0.008	Savanna Bay	0.009	0.009
Smithland Lock & Dam	0.042	0.074	Vicksburg	-0.057	0.010
West Access	-0.026	0.031	White River	0.064	0.011
Willamette River	-0.047	0.024	Wolf Island	0.001	0.009

Table 3-2. Area Comparisons for Thirty Previous Model Study Results

Large-Scale Model NAME	MODEL DIFF	MODEL MSE	Micromodel NAME	MODEL DIFF	MODEL MSE
Baleshed-Ajax	-0.406	0.213	Augusta	0.190	0.104
Blountstown	0.074	0.174	Clarendon	0.402	0.374
Buck Island	-0.248	0.149	Copeland	0.110	0.024
Chipola Cutoff	0.026	0.046	KA 1:8000 Base	0.0685	0.216
Devil's Island	-0.048	0.063	KA 1:8000 Predictive	-0.143	0.105
Dogtooth Bend	-0.011	0.179	KA 1:16,000 Base	0.284	0.319
Kate-Aubrey 1:300	-0.218	0.331	KA 1:16000 Predictive	0.111	0.184
Lake Dardanelle	0.058	0.248	Lock & Dam 24	0.128	0.063
Lock & Dam #2	-0.061	0.042	Memphis Harbor	-0.213	0.0911
Lock & Dam #4	0.257	0.156	Morgan City	0.040	0.048
Loosahatchie-Memphis	-0.003	0.023	New Madrid	-0.261	0.158
New Madrid Bar	-0.069	0.122	Salt Lake	0.205	0.0566
Redeye Crossing	-0.280	0.112	Savanna Bay	-0.171	0.0567
Smithland Lock & Dam	-0.098	0.073	Vicksburg	0.0221	0.114
West Access	0.037	0.014	White River	-0.351	0.156
Willamette River	0.028	0.028	Wolf Island	0.387	0.456

Table 3-3. Width Comparisons for Thirty Previous Model Study Results

Large-Scale Model NAME	MODEL		Micromodel NAME	MODEL	
	DIFF	MSE		DIFF	MSE
Baleshed-Ajax	-.0125	0.1091	Augusta	0.1317	0.0253
Blountstown	-.0710	0.0731	Clarendon	0.1648	0.0695
Buck Island	-.1719	0.0743	Copeland	0.0791	0.0147
Chipola Cutoff	-.0187	0.0405	KA 1:8000 Base	0.1799	0.2292
Devil's Island	-.0322	0.0169	KA 1:8000 Predictive	0.2601	0.2543
Dogtooth Bend	0.0897	0.0498	KA 1:16,000 Base	0.1938	0.1910
Kate-Aubrey	-.1636	0.1090	KA 1:16000 Predictive	0.4067	0.3484
Lake Dardanelle	-.0845	0.1788	Lock & Dam 24	-0.0361	0.0043
Lock & Dam #2	-.0349	0.0186	Memphis Harbor	0.0713	0.0268
Lock & Dam #4	0.1129	0.0393	Morgan City	0.0524	0.0233
Loosahatchie-Memphis	0.0873	0.0346	New Madrid	-0.1803	0.0714
New Madrid Bar	-.0091	0.0702	Salt Lake	0.0230	0.0045
Redeye Crossing	-.1472	0.0618	Savanna Bay	-0.00804	0.0220
Smithland Lock & Dam	-.0027	0.0007	Vicksburg	0.1140	0.0399
West Access	0.0334	0.0024	White River	0.0892	0.0426
Willamette River	-.0041	0.0132	Wolf Island	0.1000	0.0383

Table 3-4. Hydraulic Depth Comparisons for Thirty Previous Model Study Results

Large-Scale Model NAME	MODEL		Micromodel NAME	MODEL	
	DIFF	MSE		DIFF	MSE
Baleshed-Ajax	-0.394	0.177	Augusta	0.056	0.062
Blountstown	0.150	0.165	Clarendon	0.208	0.155
Buck Island	-0.080	0.141	Copeland	0.031	0.011
Chipola Cutoff	0.077	0.079	KA 1:8000 Base	-0.007	0.275
Devil's Island	-0.012	0.047	KA 1:8000 Predictive	-0.257	0.198
Dogtooth Bend	-0.094	0.127	KA 1:16,000 Base	0.156	0.395
Kate-Aubrey	-0.095	0.099	KA 1:16000 Predictive	-0.155	0.218
Lake Dardanelle	0.162	0.093	Lock & Dam 24	0.174	0.090
Lock & Dam #2	-0.019	0.043	Memphis Harbor	-0.267	0.103
Lock & Dam #4	0.137	0.095	Morgan City	-0.003	0.049
Loosahatchie-Memphis	-0.072	0.028	New Madrid	-0.059	0.171
New Madrid Bar	-0.079	0.093	Salt Lake	0.178	0.043
Redeye Crossing	-0.090	0.084	Savanna Bay	-0.134	0.093
Smithland Lock & Dam	-0.100	0.070	Vicksburg	-0.094	0.059
West Access	0.003	0.009	White River	-0.380	0.206
Willamette River	0.031	0.014	Wolf Island	0.261	0.263

Table 3-5. Width/Depth Ratio Comparisons for Thirty Previous Model Study Results

Large-Scale Model NAME	MODEL DIFF	MODEL MSE	Micromodel NAME	MODEL DIFF	MODEL MSE
Baleshed-Ajax	0.729	1.107	Augusta	-0.010	0.154
Blountstown	-0.113	0.142	Clarendon	0.045	0.131
Buck Island	0.008	0.176	Copeland	0.054	0.028
Chipola Cutoff	-0.038	0.092	KA 1:8000 Base	0.585	2.099
Devil's Island	0.024	0.053	KA 1:8000 Predictive	1.137	3.446
Dogtooth Bend	0.348	0.422	KA 1:16,000 Base	0.264	0.662
Kate-Aubrey	-0.033	0.162	KA 1:16000 Predictive	1.031	2.277
Lake Dardanelle	-0.199	0.196	Lock & Dam 24	-0.145	0.053
Lock & Dam #2	0.036	0.095	Memphis Harbor	0.532	0.461
Lock & Dam #4	0.019	0.114	Morgan City	0.102	0.077
Loosahatchie-Memphis	0.207	0.181	New Madrid	0.177	0.964
New Madrid Bar	0.112	0.203	Salt Lake	-0.129	0.028
Redeye Crossing	0.018	0.130	Savanna Bay	0.288	0.302
Smithland Lock & Dam	0.249	0.366	Vicksburg	0.284	0.225
West Access	0.040	0.012	White River	0.996	1.457
Willamette River	-0.028	0.022	Wolf Island	0.011	0.285

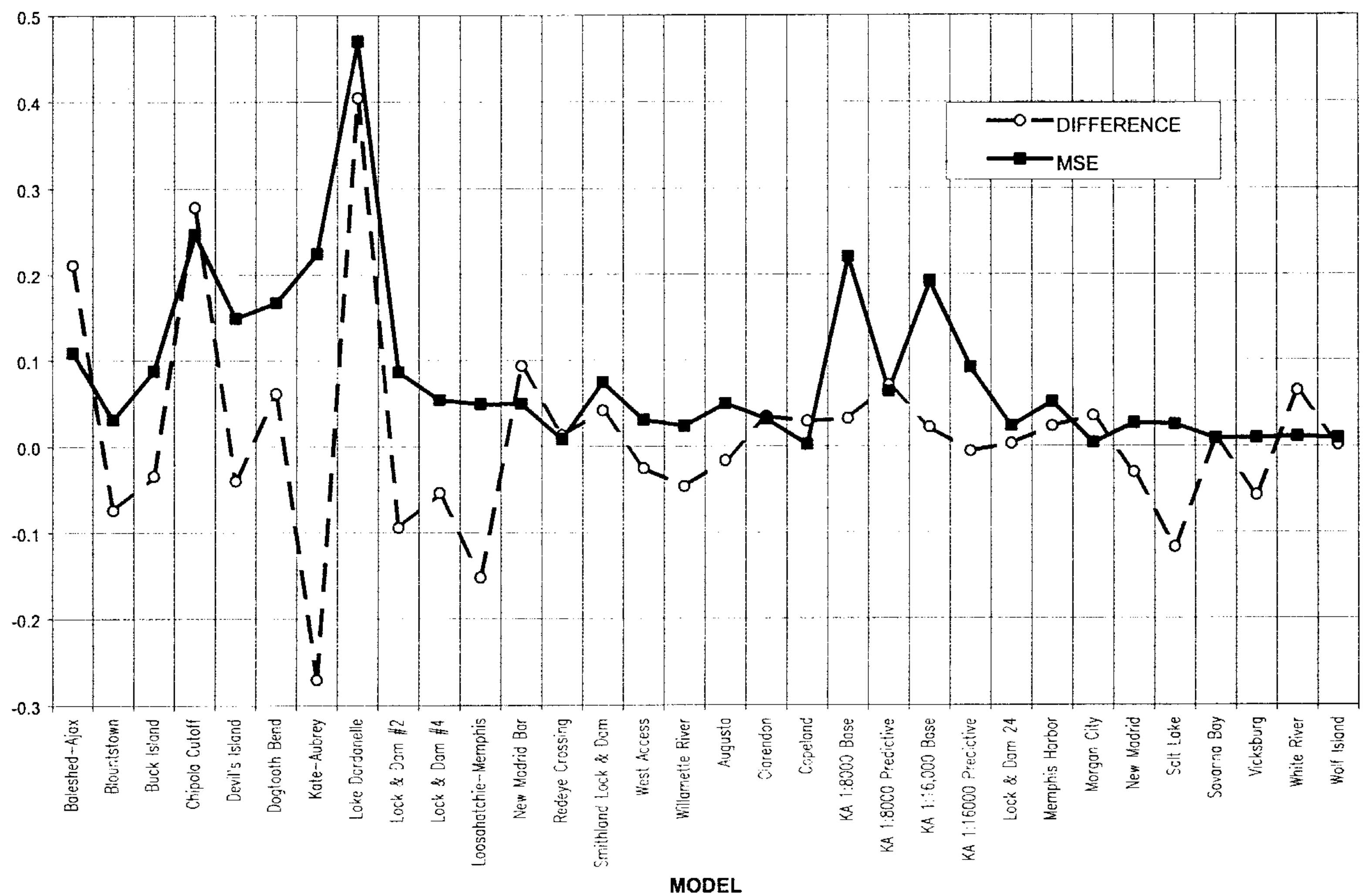

Figure 3-1 Thalweg Differences and MSE

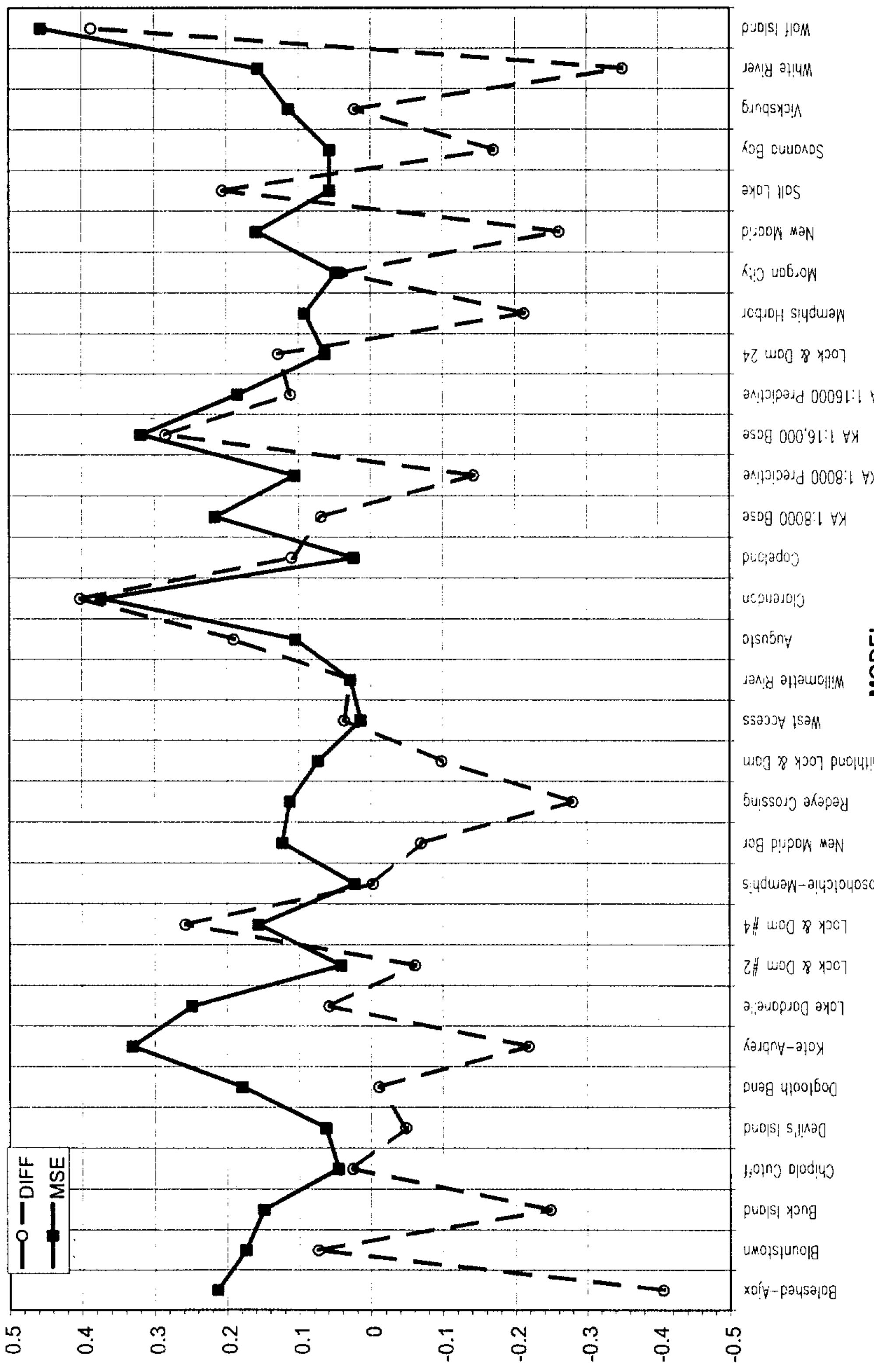

Figure 3-2 Area at 0.0 LWRP Differences and MSE

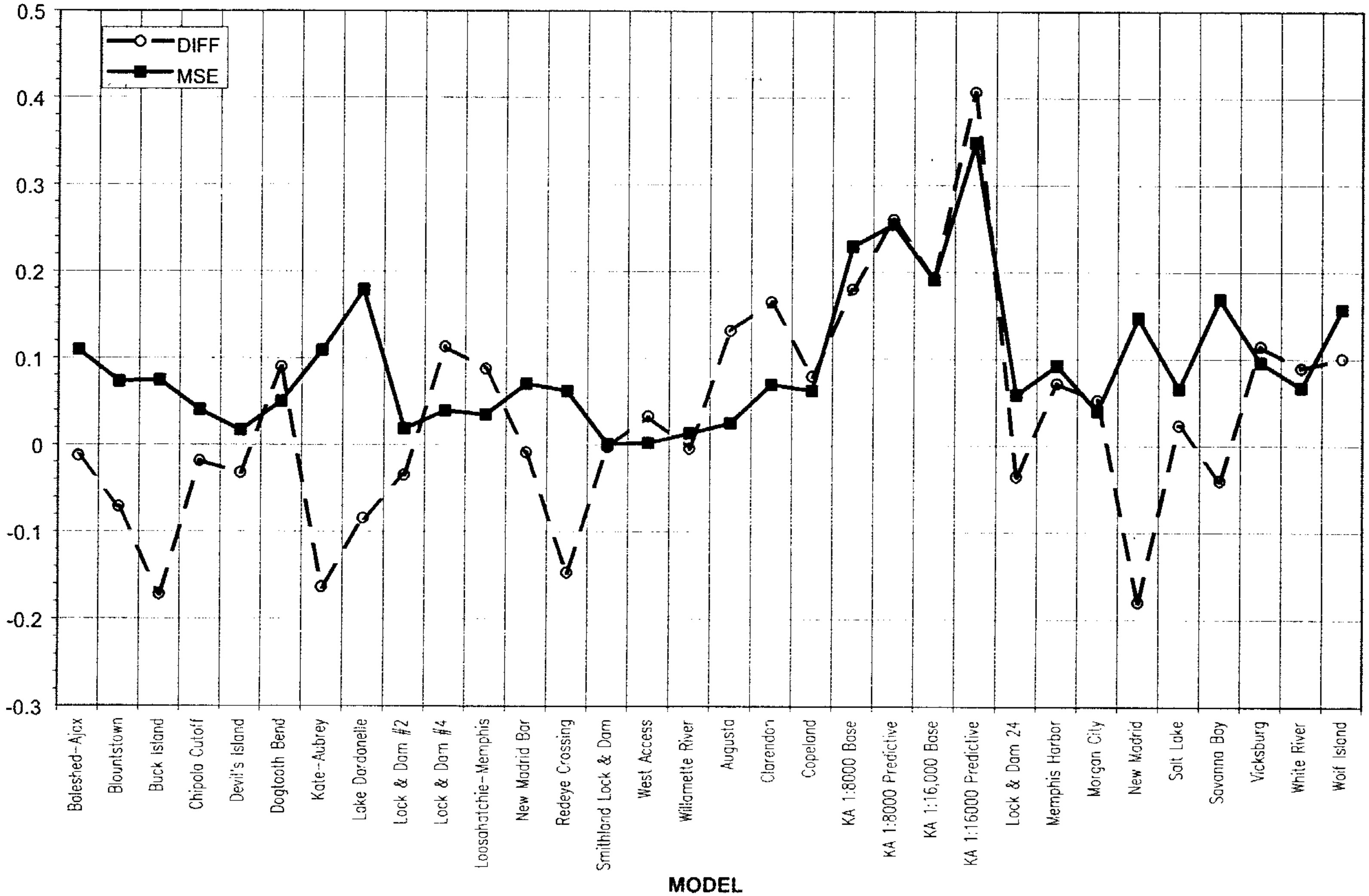

Figure 3-3 Width at 0.0 LWRP Differences and MSE

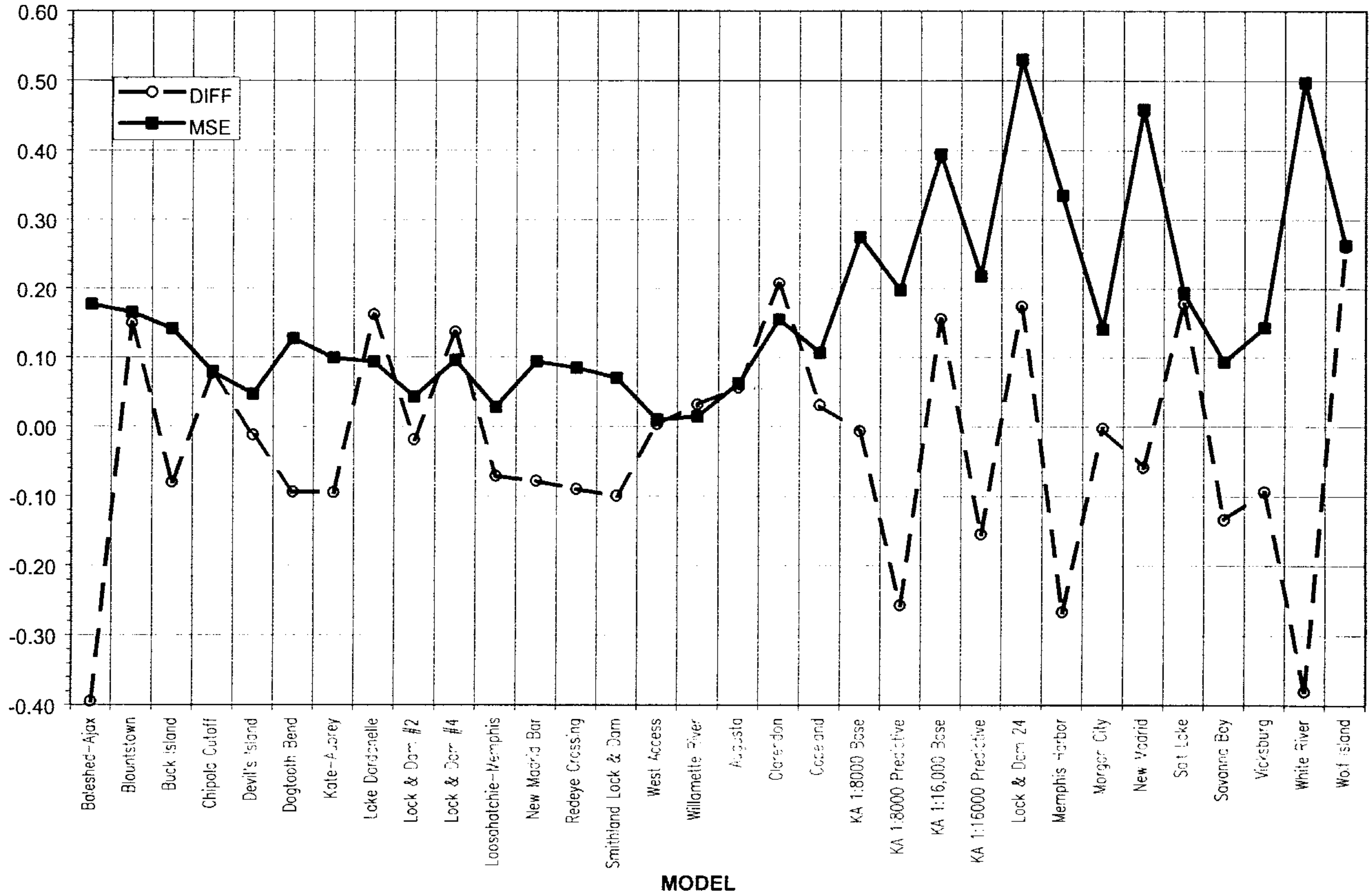

Figure 3-4 Hydraulic Depth at 0.0 LWRP Differences and MSE

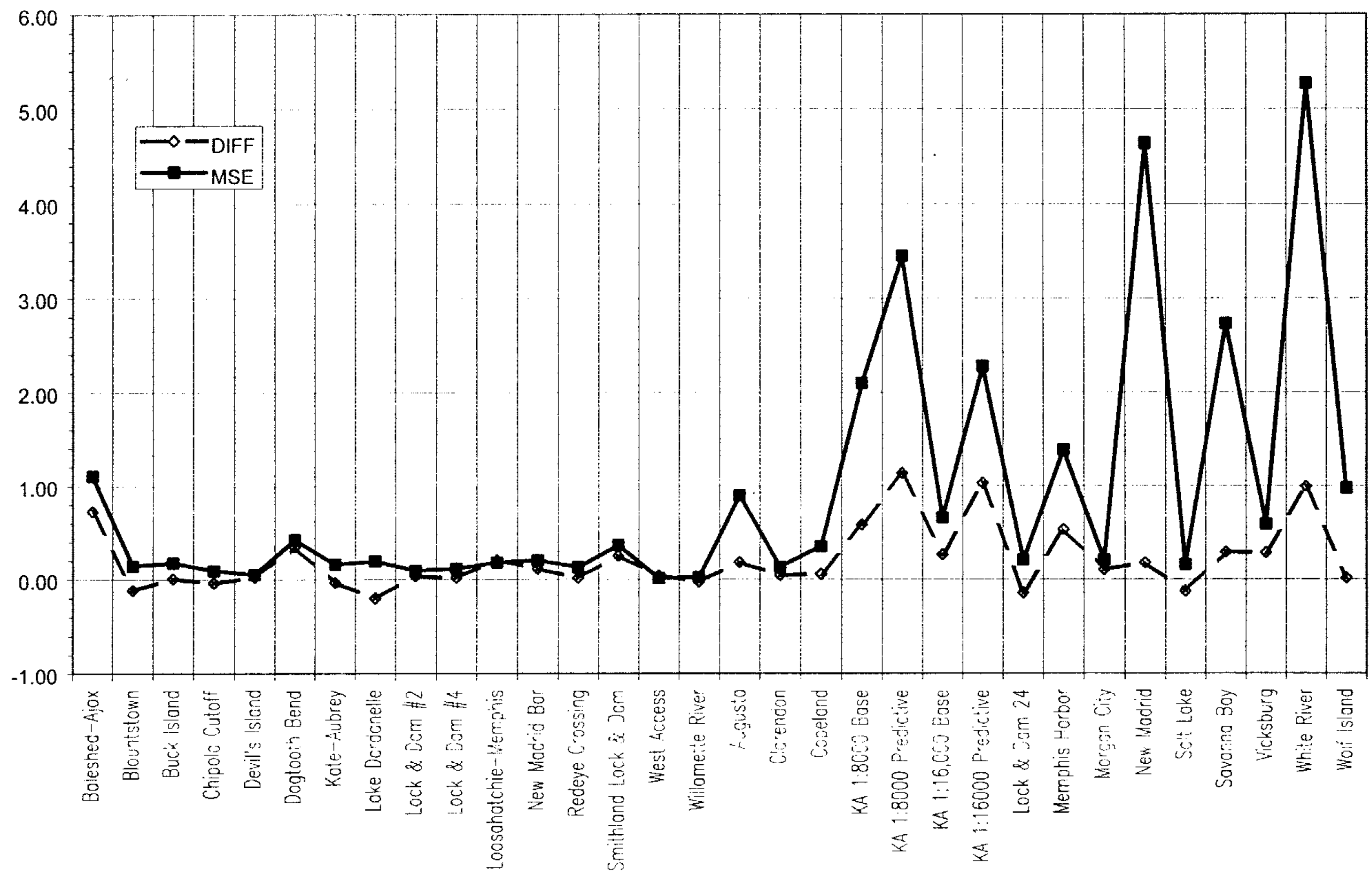

Figure 3-5 Width/Depth Ratio at 0.0 LWRP Differences and MSE

APPENDIX A

KATE-AUBREY CASE STUDY

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A. KATE-AUBREY CASE STUDY

A.1. Case Study

The Kate-Aubrey reach of the Mississippi River was selected for detailed study in the present investigation because a large amount of data existed for the prototype. Additionally, a large-scale coal-bed model had previously been constructed and utilized for channel improvements between approximately River Miles 785 and 800. Although earlier model studies of the Kate-Aubrey reach aided in design of navigation improvements, problems persist in the area as of 2001. The need for additional model studies of this reach provided an opportunity to explore model similarity requirements. For this reason, the current investigation included construction of two micro-scale models (micromodels) of the Kate-Aubrey reach to aid in assessing and validating the micro-scale methodology. Construction of the micromodels for Kate-Aubrey also provided the tools needed to assess further improvements for navigation. Alternative analysis related to these improvements are not included in the present investigation.

A.1.1. History of Kate-Aubrey Reach.

Franco (1978) describes the Kate-Aubrey reach beginning just prior to 1968 and continuing through 1975. Franco (1978) also provides a description of the prototype and model study results obtained with an earlier sand-bed physical model. The reach had considerable variability in the thalweg location from year to year even with training structures constructed to restrict adjustment of the navigation channel alignment. This variability resulted in several shallow crossings, most notably in the vicinity of River Mile 790. Following a major flood event in 1973, the navigation channel exhibited an almost ninety-degree crossing from the left descending bank to the right descending bank at River mile 793.4. Significant dredging was required on at least an annual basis to maintain a navigable channel in this area. For example, dredging at Kate-Aubrey for the four year period between 1976 and 1979 averaged 4,000,000 cubic yards annually. The high annual cost of maintenance prompted the use of a physical model to study alternative plans for improving the reach.

A coal-bed physical model was designed and constructed by WES in the late-1970's to mid-1980's to assist river engineers in developing an improvement plan for the reach. The coal-bed model was calibrated to 1975 and 1976 prototype conditions. Prototype hydrographic surveys existed for each year beginning in 1968 through 1979 with some years having only partial coverage of the entire reach. Hydrographic surveys in years following 1980 were at one to three year intervals. Hydrographic surveys for 1973, 1975, and 1976 were selected for calibration of the micromodels to coincide with the period used in large-model verification. Use of this prior time period as the basis for calibration permitted use of the three model scales in assessing scale effects on similarity. A further benefit of using the prior time period for calibration was that a more recent prototype condition could be placed in the model to assess the predictive capability of the micromodels. The predictive analysis is described in subsequent sections.

The Kate Aubrey micromodels were designed to encompass the range of horizontal scales typically used in micromodeling. Horizontal scales of 8,000:1 and 16,000:1 were selected. The same bank lines, upstream and downstream limits, and physical boundary conditions were used for both micromodels. Ranges utilized for analysis of the two micromodels were the same (shown in Figure A-1). However, these Range locations were different than those used in analyzing the large-scale model. Figure A-2 shows the Ranges used for the large-scale Kate-Aubrey model. The model reach length was also different. The 1:300 model extended over river miles 785.5 to 797.0 and the two micromodels extended between river miles 786.0 to 803.0.

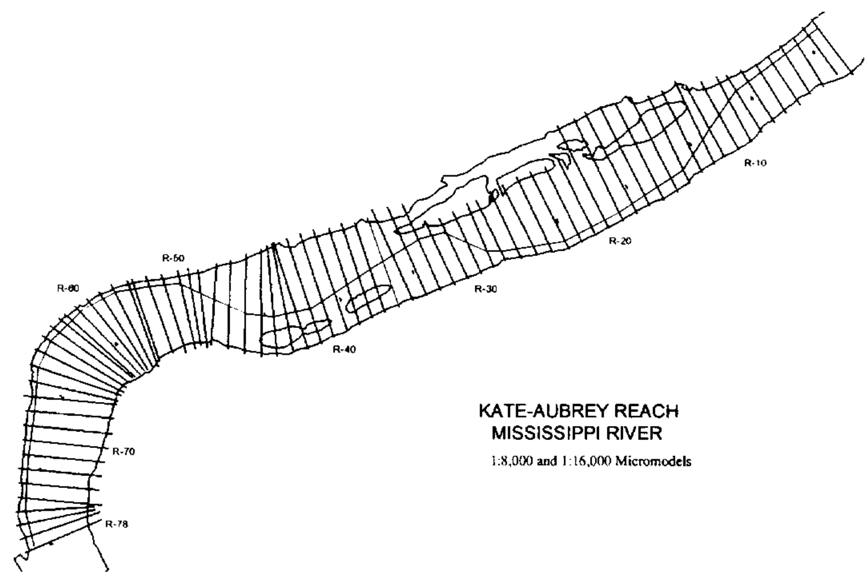

Figure A-1 Model Extent and Range Locations for 1:8,000 and 1:16,000 Micromodels

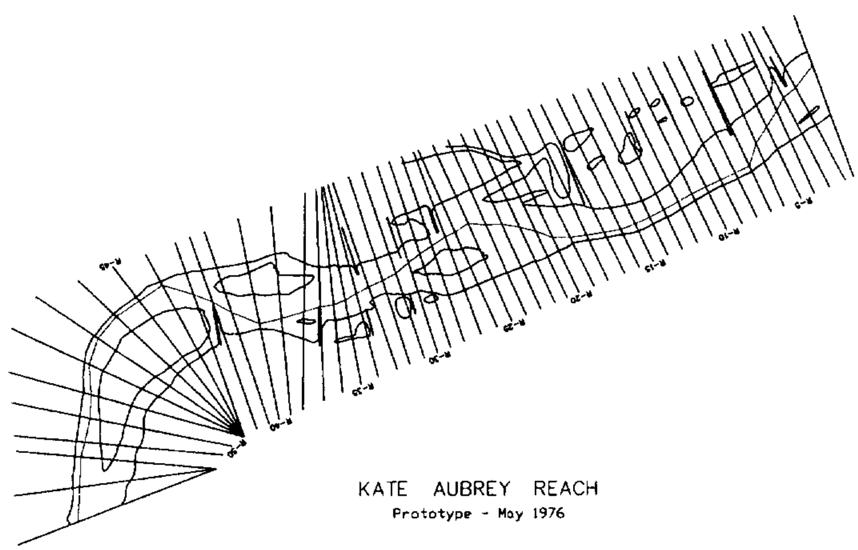

Figure A-2 Model Extent and Range Locations for 1:300 Model

A.1.2. Large-Scale Models.

An example of large-scale model is the Kate-Aubrey model of the Mississippi River conducted by WES. A photograph of the large-scale Kate-Aubrey physical sediment model is shown in Figure A-3 The Kate-Aubrey reach is located north of Memphis, Tennessee between river miles 785 and 797. The purpose of the study was to determine the extent of shoaling between river miles 788 and 792.5. The model used for the study was a loose-bed model with crushed coal sediment material constructed to scales of 1:300 horizontal and 1:100 vertical (model to prototype, respectively). The coal had a median diameter of 4 mm and a specific gravity of 1.30. Prototype data used in this study were bathymetric surveys for May 1975 and May 1976. Prototype bathymetry for 1975 and 1976 are shown in Figures A-4 and A-5, respectively.

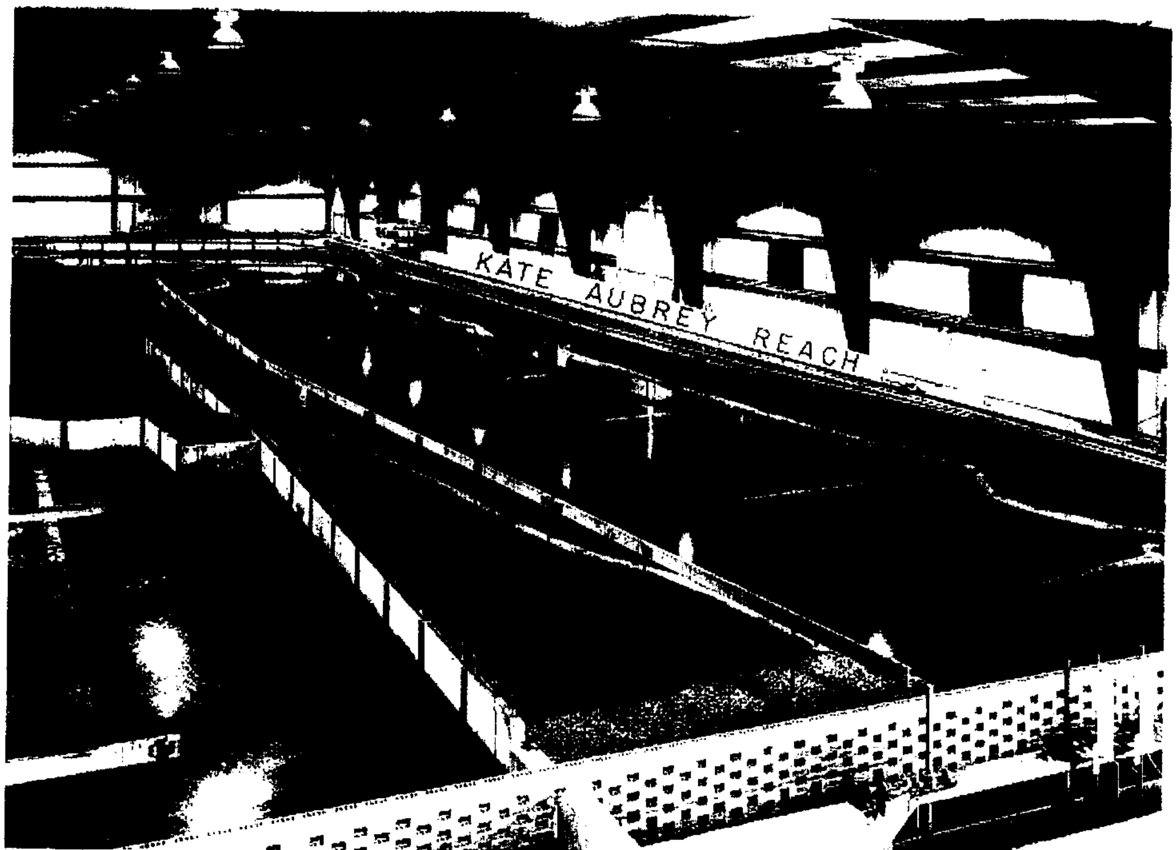

Figure A-3 Kate-Aubrey Large-Scale Physical Sediment Model

The model was initially formed (or molded) to the 1975 prototype bathymetry. A model discharge hydrograph was developed from historical stage and discharge records for the prototype. The resulting hydrograph (also referred to as the verification hydrograph) was used to simulate the period between May 1975 and May 1976 in the model. Sediment material was added to the upstream end of the model (a sediment feed system was used) during simulations to maintain a desired rate of sediment load relative to water discharge for the reach. This produced a model sediment rating curve. The model slope, rate of sediment load and water discharge, and boundary conditions (e.g. tailgate setting and bank roughness) were adjusted over the course of several repetitions until the final model bathymetry reproduced the May 1976 prototype conditions. Each repetition began with the May 1975 prototype condition formed in the model. The model was then used to simulate the verification hydrograph (including the corresponding sediment rating curve) to obtain model bathymetry to compare with the May 1976 prototype survey. The large-scale models employed a verification process to establish basic model operating parameters. The verification procedure relied on a visual comparison of model and prototype bathymetry as described in Gaines (2002). Once the May 1976 prototype condition was reproduced in the model, the model was considered verified. Model bathymetry after verification is shown in Figure A-6.

Analysis of morphologic parameters provides a quantitative means for assessing model and prototype agreement. A graphic comparison of individual Range values for each parameter provides a first view of model and prototype agreement. Thalweg position at each range for the large-scale Kate-Aubrey model is shown in Figure A-7. Hydraulic depth, water surface width, cross-section area, and width to depth ratio at an elevation of 0.0 LWRP are shown in Figures A-8, A-9, A-10, and A-11, respectively. These graphs illustrate the variability inherent in the prototype as the channel boundary continually adjusts to changes in discharges and sedimentation processes over time. The model results (scaled to prototype coordinates) provide a ready comparison of how well model trends reproduce prototype trends.

Examination of the bathymetric data (Figures A-4 to A-6) and individual parameter graphs (Figures A-7 to A-11) provides a general assessment of prototype variability and model similarity as shown in Table A-1. However, a quantifiable expression of model similarity is not expressed by individual parameter graphs or by visual assessment of the bathymetric data.

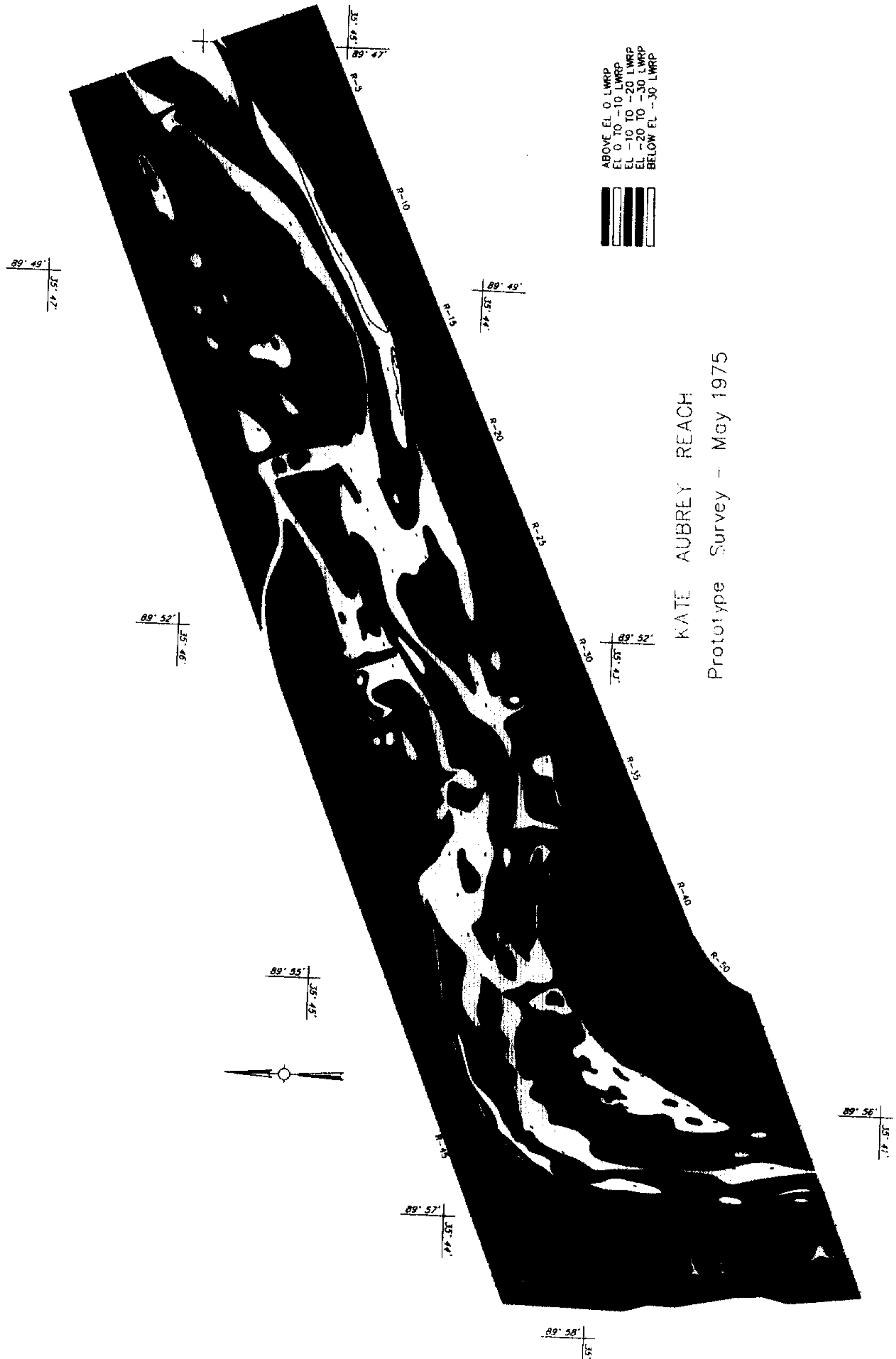

Figure A-4 1975 Prototype Bathymetry, Kate-Aubrey Reach

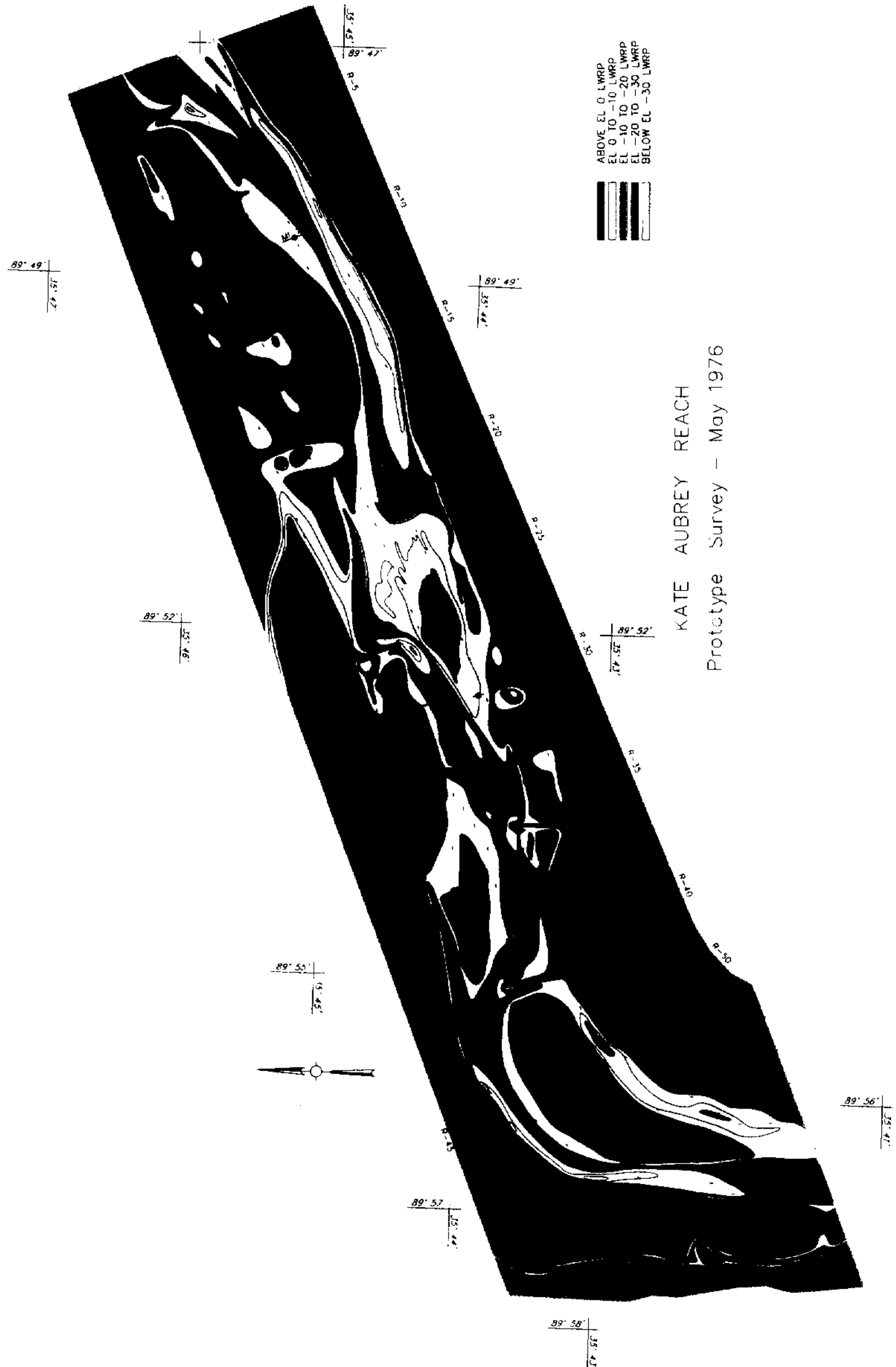

Figure A-5 1976 Prototype Bathymetry, Kate-Aubrey Reach

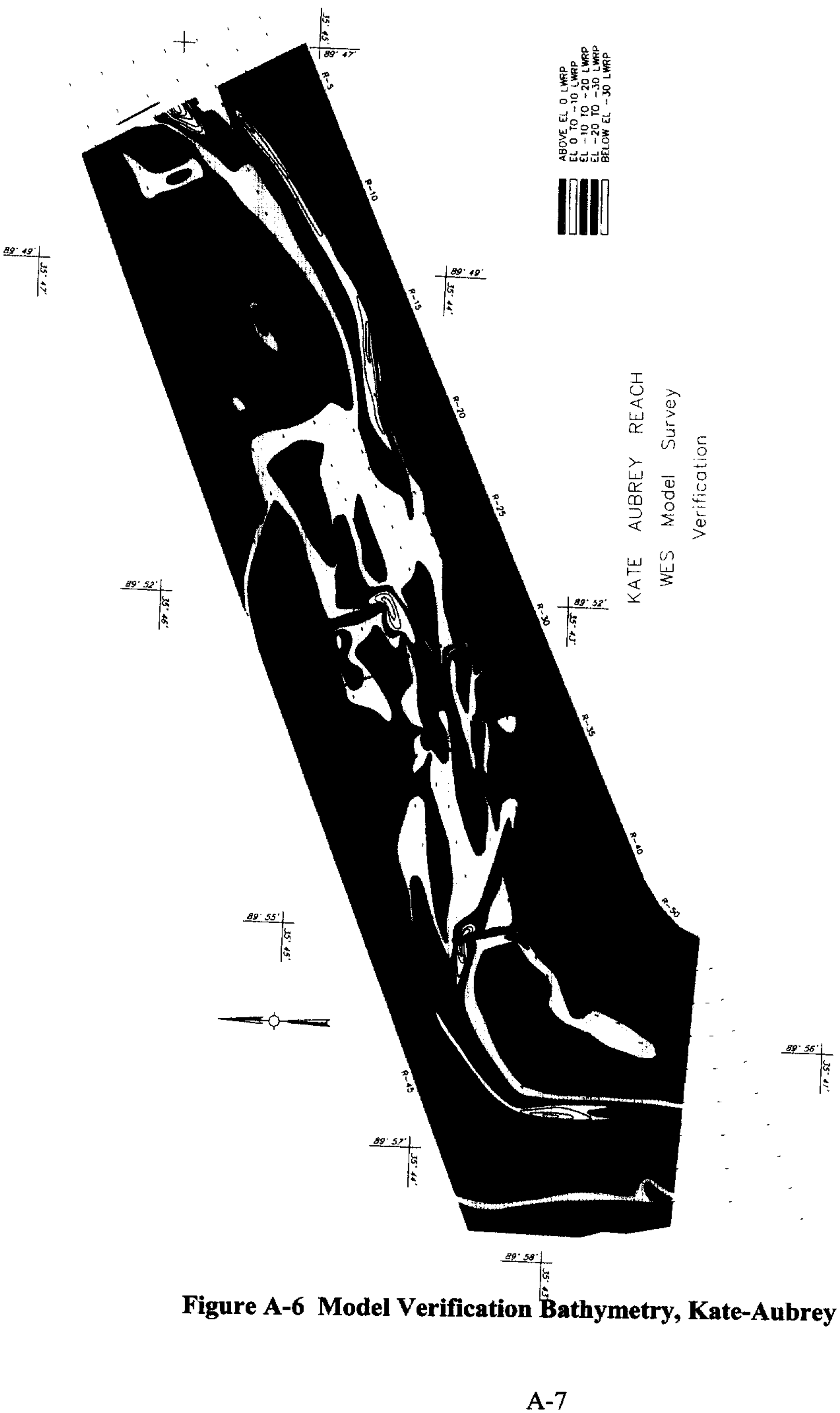

Figure A-6 Model Verification Bathymetry, Kate-Aubrey Reach

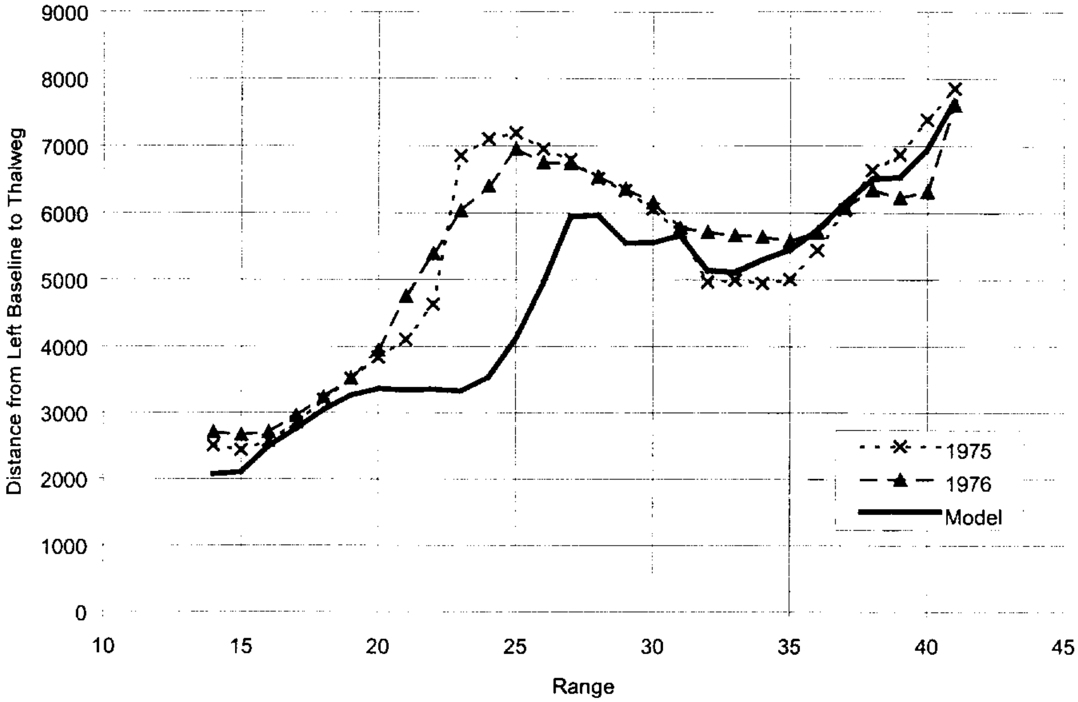

Figure A-7 Thalweg Position, 1:300 Kate-Aubrey Model

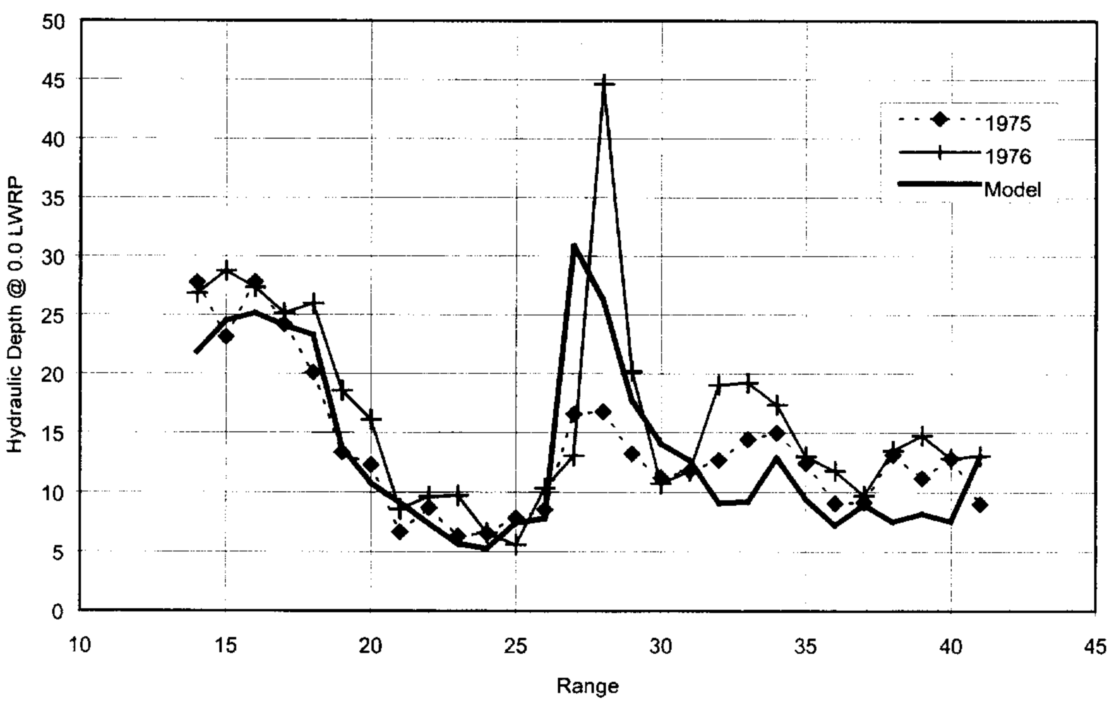

Figure A-8 Hydraulic Depth, 1:300 Kate Aubrey Model

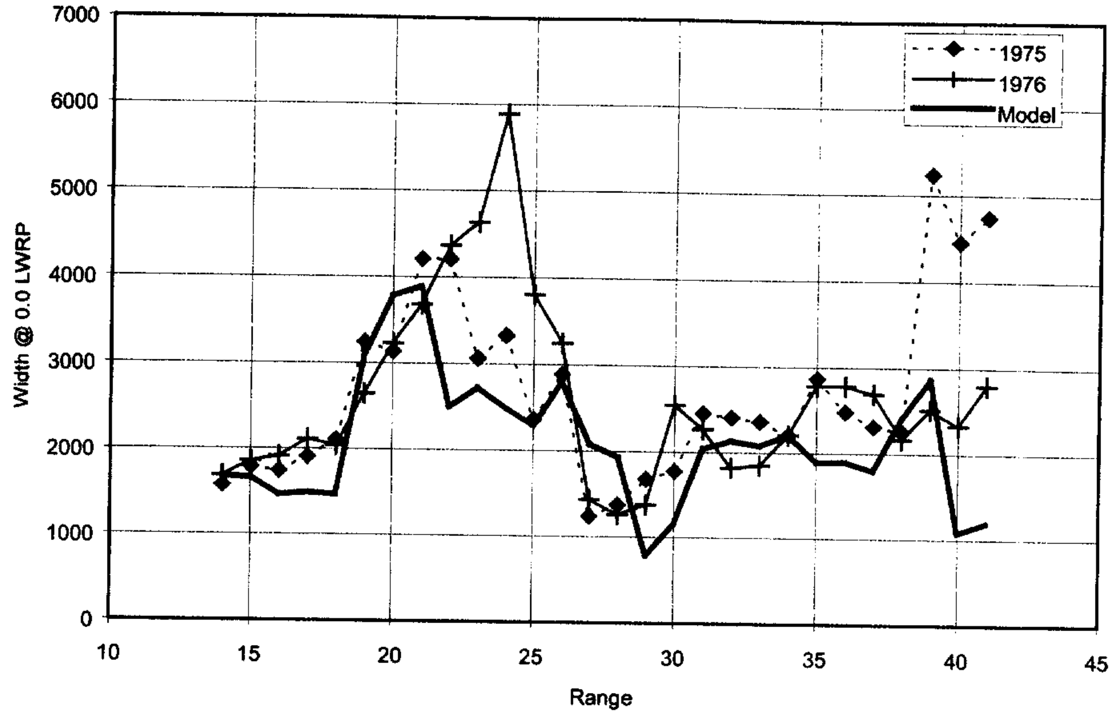

Figure A-9 Width, 1:300 Kate Aubrey Model

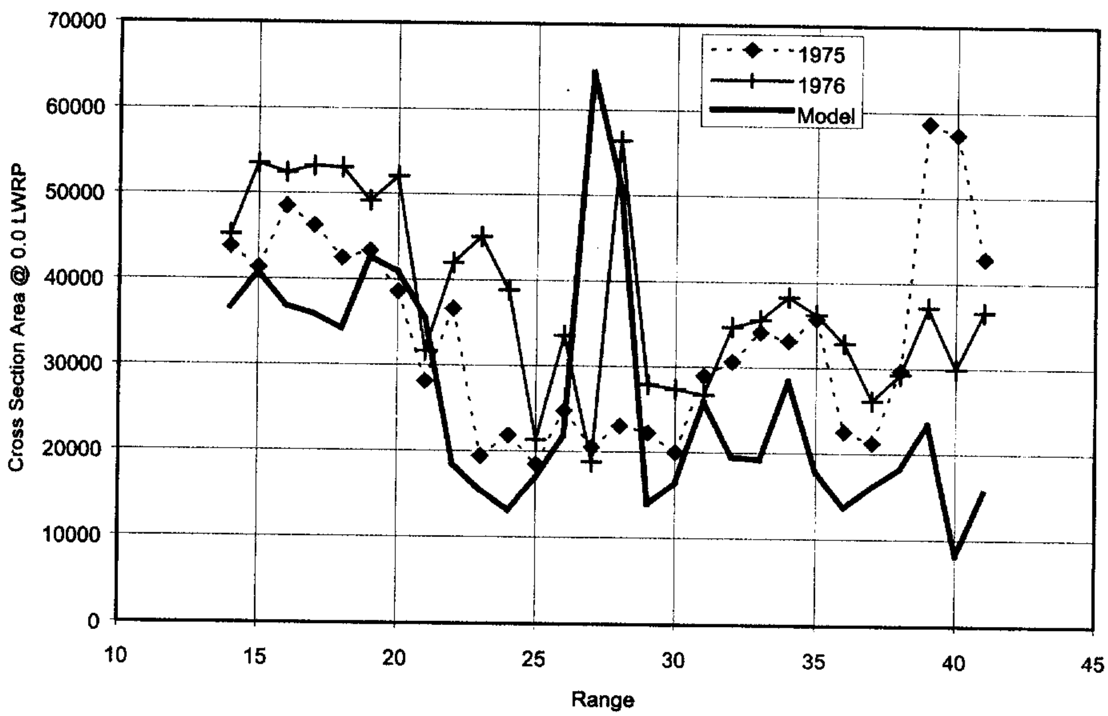

Figure A-10 Area, 1:300 Kate Aubrey Model

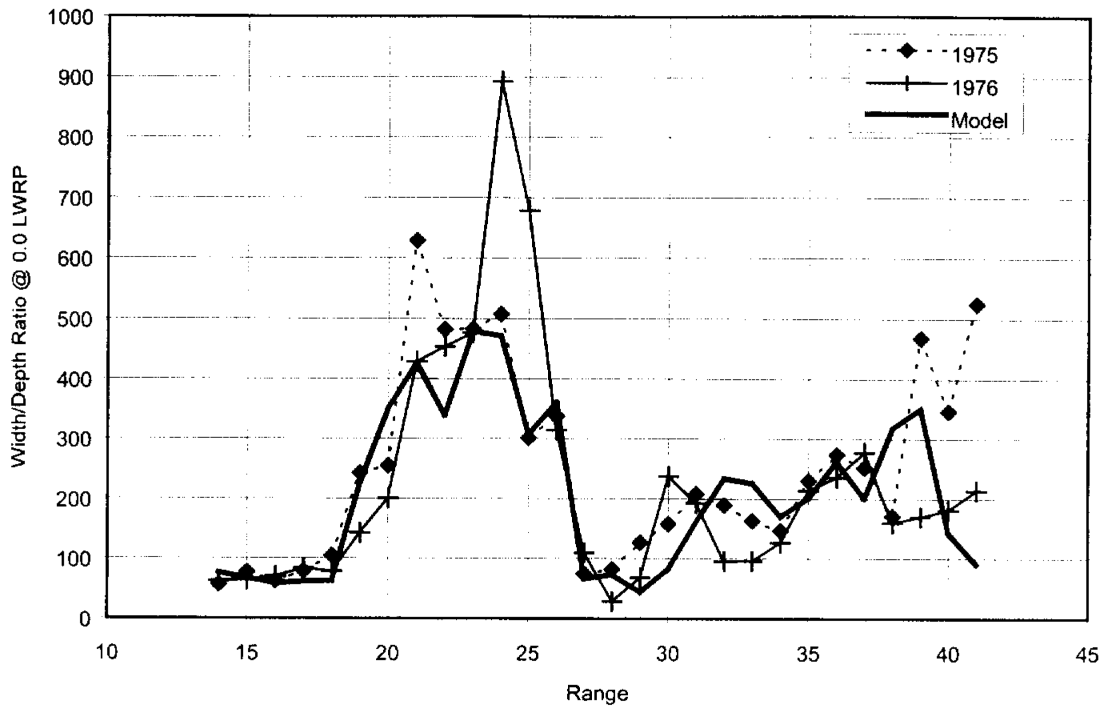

Figure A-11 Width to Depth Ratio, 1:300 Kate Aubrey Model

Table A-1 Morphologic Parameter Assessment, Kate-Aubrey Model

Morphologic Parameter	Model	Prototype
Thalweg Position	Thalweg not reproduced between R20 and R28	Thalweg more variable in areas, particularly R20 to R28, or R32-35.
Hydraulic Depth at 0.0 LWRP	Appears to match prototype trends overall, model depth too low R30-R40	High degree of variability between 1975 and 1976 surveys
Width at 0.0 LWRP	Overall width too low particularly R21-R26	High degree of variability between 1975 and 1976 surveys especially R21-R26, and R39-41
Area at 0.0 LWRP	Appears to match prototype trends exhibited in 1975 survey	Variability of 5000 to 10000 square feet overall but much higher R2A-R29
Width/Depth Ratio at 0.0 LWRP	Matches 1975 survey best (the molded case), but area low throughout reach, except where area is high	Large variability R24-R26 and R39-41

A.1.3. **Small-Scale Models.**

Two small-scale models (micromodels) of the Kate-Aubrey reach were also developed as part of the present investigation. The Kate-Aubrey micromodels extended between river miles 783 and 803. A photograph of the small-scale Kate-Aubrey physical sediment model is shown in Figure A-12. The purpose of the micromodel studies was to determine the effect of scale on model results and to evaluate the model's predictive capability by comparing a predicted result to actual prototype response. The models used for the study were loose-bed models with Urea PlastiGrit sediment having a specific gravity of 1.48. Scales for these models were 1:16,000 horizontal and 1:900 vertical for the smaller model and 1:8,000 horizontal and 1:600 vertical for the larger model. Median particle sizes were 0.73mm and 0.62mm for the smaller and larger micromodels, respectively. Prototype data used in this study were bathymetric surveys for June 1973, May/June 1975 and May/June 1976. Prototype bathymetry is shown in Figures A-13, A-14, A-15 for the 1973, 1975, and 1976 surveys respectively. Both models were designed with

Figure A-12 Kate-Aubrey Small-Scale Physical Sediment Model

rigid, vertical banks at the location of prototype top bank. Both small-scale models utilized a synthetic discharge hydrograph that approximated a sine wave function between maximum and minimum discharge settings. Sediment was recirculated in the small-scale models (no external sediment feed system was used). To achieve a state of calibration in the small-scale models (termed calibration as opposed to verification as used for the large-scale models) the model was operated through several hydrograph cycles to achieve a state of equilibrium.

Equilibrium in the small-scale models represented the condition where net sediment transport and bed bathymetry remained consistent for successive cycles (there was no net aggradation or degradation over time observed in the model). Once equilibrium was obtained, the resulting model bathymetry was visually compared to the three prototype surveys to assess whether the model had reproduced prototype conditions. The model slope, discharge, and boundary conditions (e.g. downstream weir elevation and bank roughness) were adjusted over the course of several simulation periods until the final model bathymetry reproduced the observed prototype conditions. Visual comparison of model bathymetry to prototype bathymetry generally focused on trends in color coded contour elevations and thalweg position through the reach. Bathymetry for the calibrated 1:8,000 micromodel is shown in Figure A-16. Bathymetry for the calibrated 1:16,000 micromodel is shown in Figure A-17. All micromodel bathymetry was obtained after a consistent procedure of shutting down the models. This method involved closing the tailgate to flow and stopping the inflow at the end of the hydrograph peak. The model was then allowed to slowly drain thereby preventing disruption of the bed as flow exited the model.

Analysis of the five morphologic parameters described in Section 1.2 was performed for the small-scale models. Comparison of individual Range values for each morphologic parameter was performed graphically by plotting parameter values by Range just as done for the large-scale model. The 1:8000 micromodel parameter values for thalweg position, hydraulic depth, width, width to depth ratio, and area are shown in Figure A-18, Figure A-19, Figure A-20, Figure A-21, and Figure A-22, respectively.

Thalweg position, hydraulic depth, width, width to depth ratio, and area for the 1:16,000 micromodel are shown in Figure A-23, Figure A-24, Figure A-25, Figure A-26, and Figure A-27, respectively.

The prototype bathymetry used in micromodel calibration was consistent with that used for the large-scale models except an additional survey, 1973, was included.

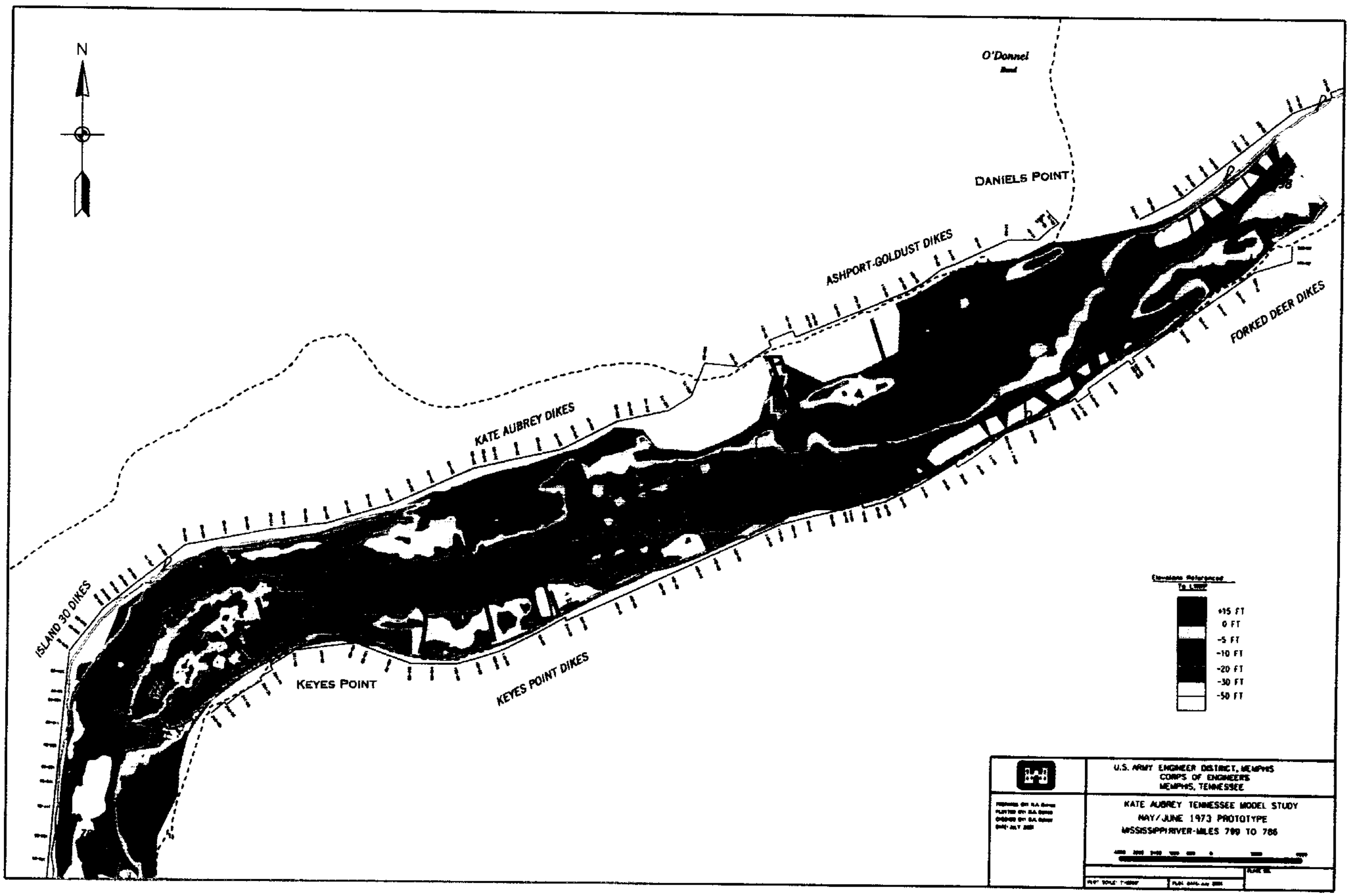

Figure A-13 1973 Prototype Bathymetry, Kate-Aubrey Reach Small-Scale Models

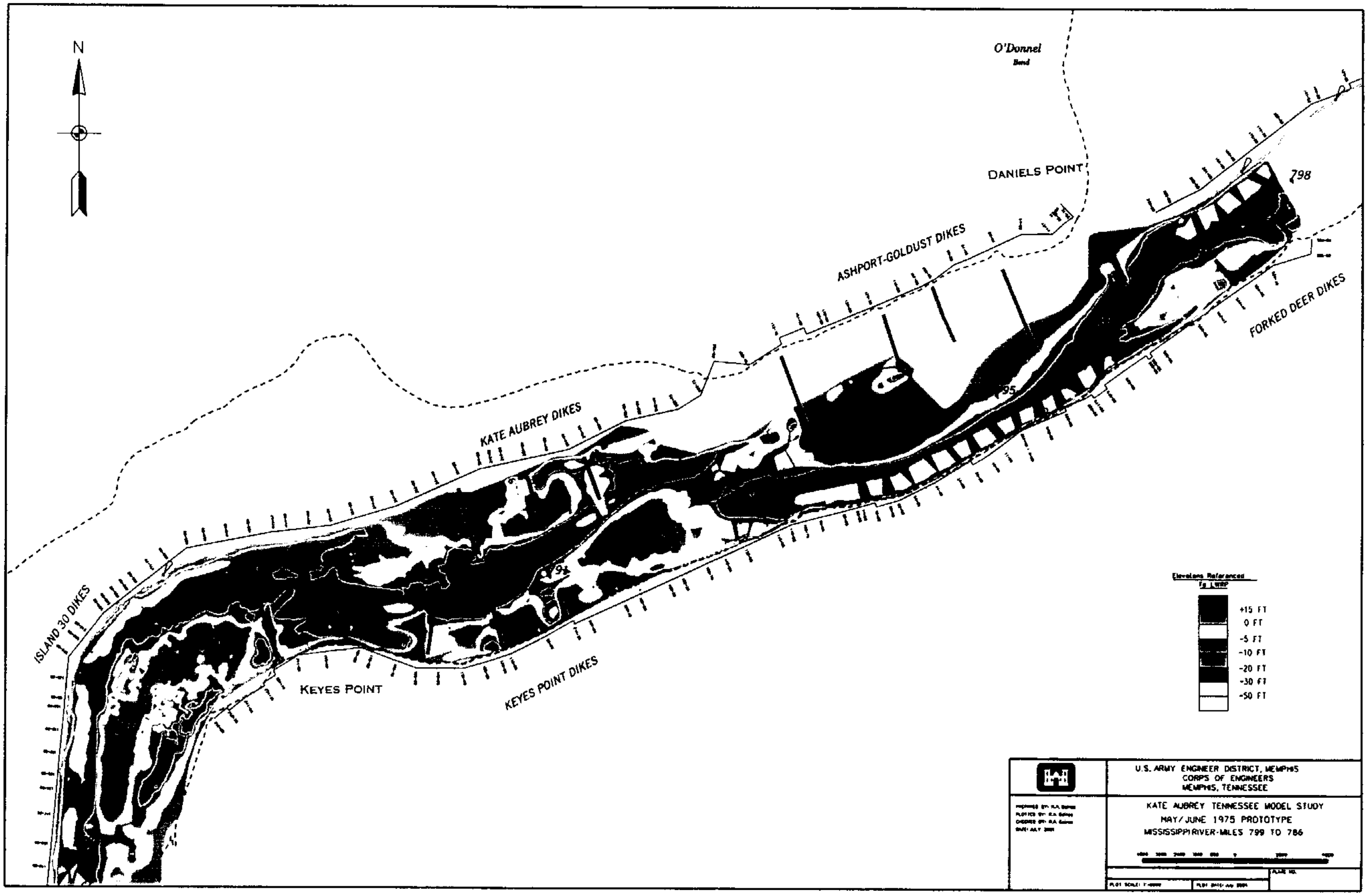

Figure A-14 1975 Prototype Bathymetry, Kate-Aubrey Reach Small-Scale Models

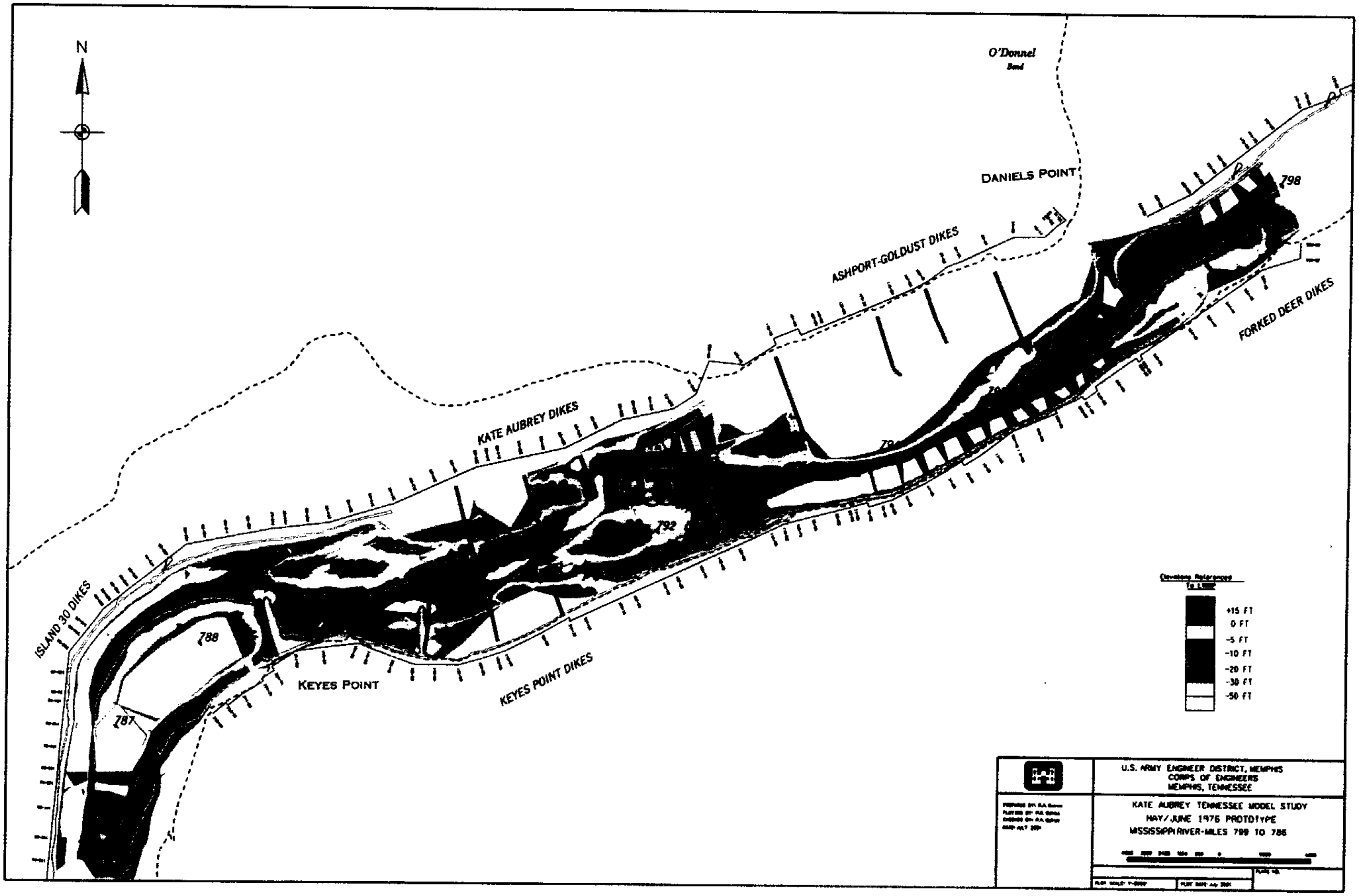

Figure A-15 1976 Prototype Bathymetry, Kate-Aubrey Reach Small-Scale Models

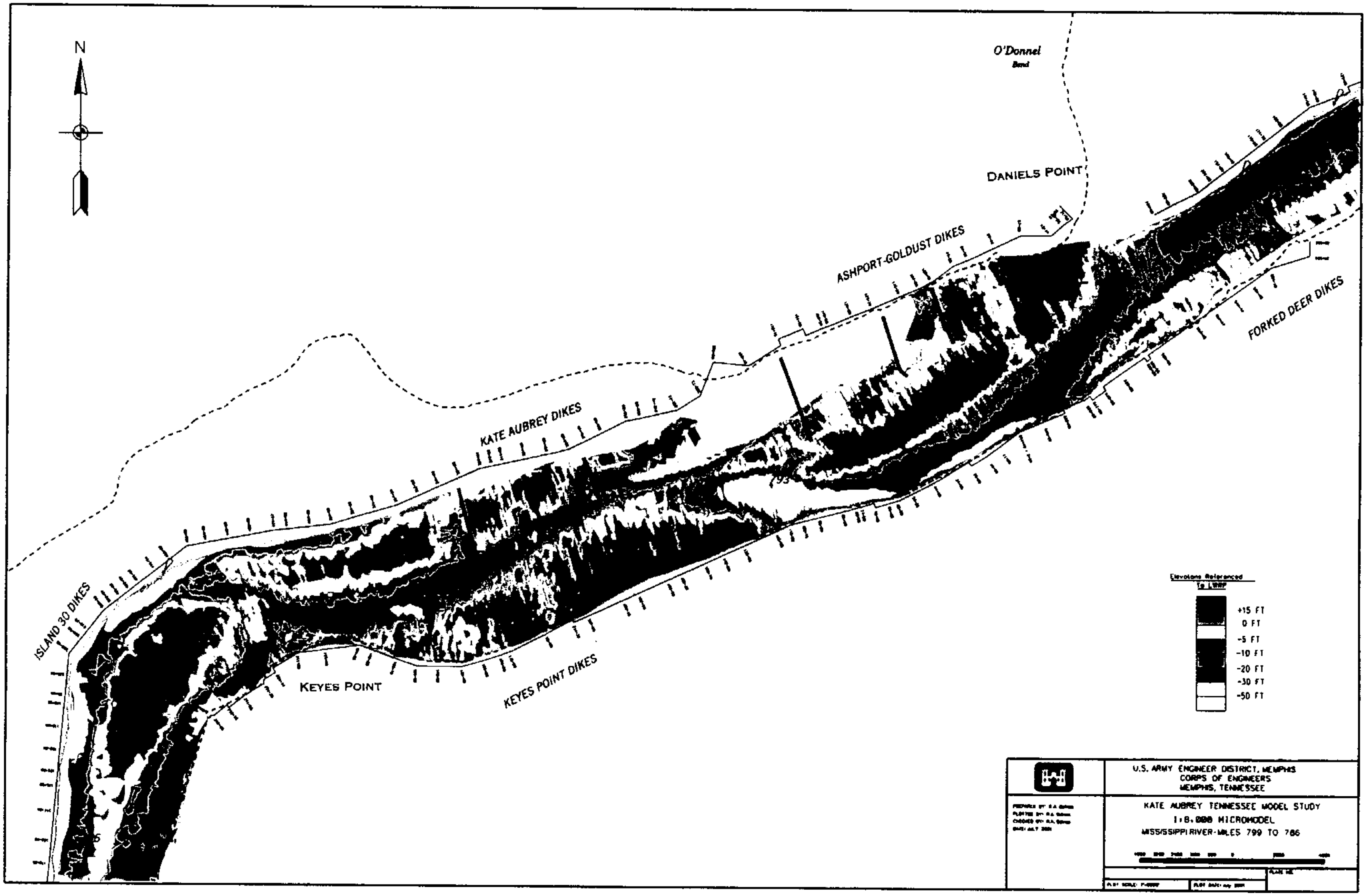

Figure A-16 Calibrated Bathymetry, Kate-Aubrey Reach 1:8,000 Model

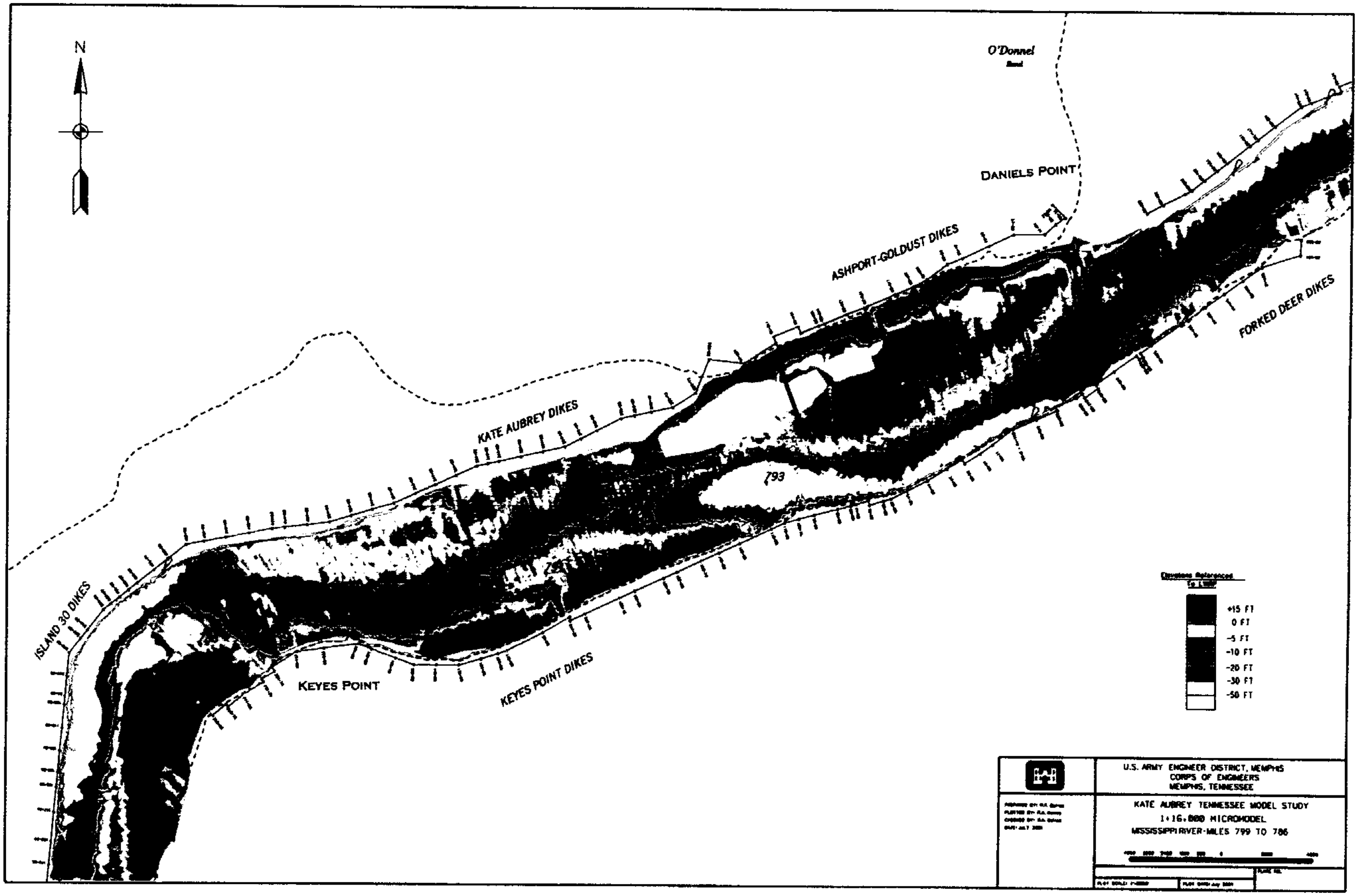

Figure A-17 Calibrated Bathymetry, Kate-Aubrey Reach 1:16,000 Model

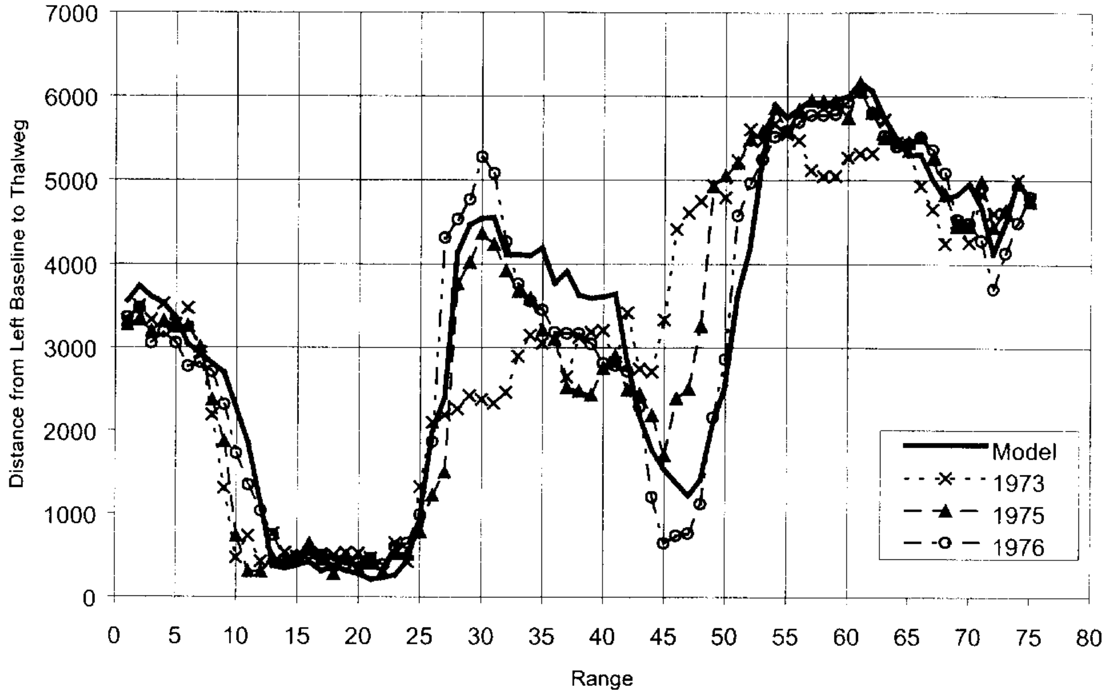

Figure A-18 Thalweg Position, 1:8000 Kate-Aubrey Micromodel

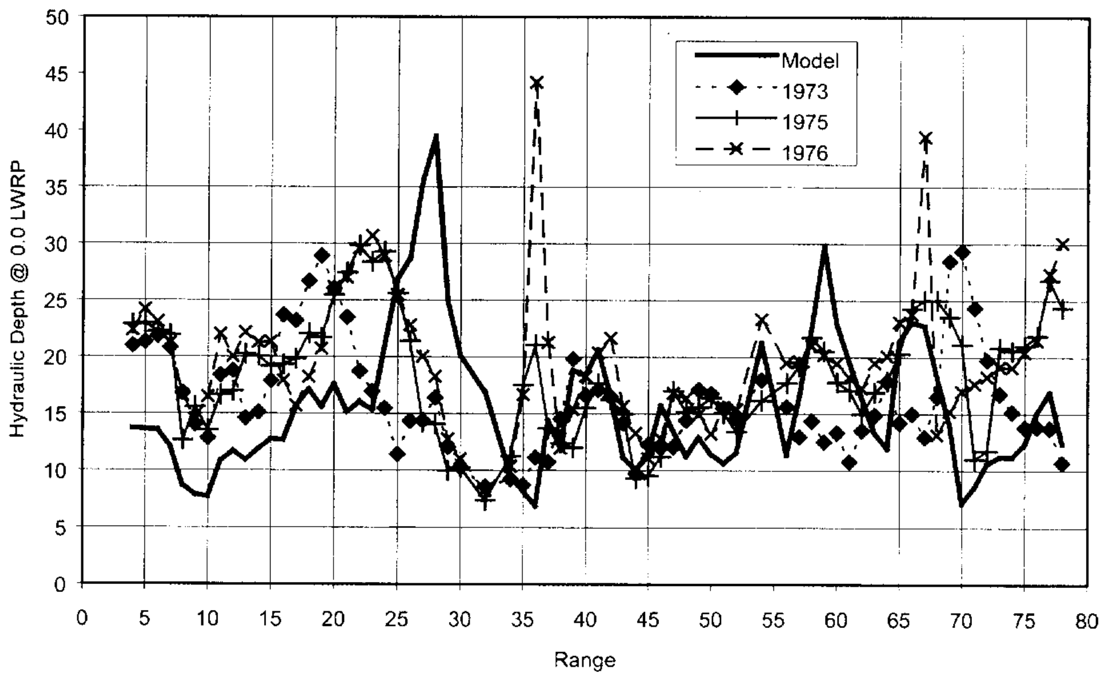

Figure A-19 Hydraulic Depth, 1:8000 Kate-Aubrey Micromodel

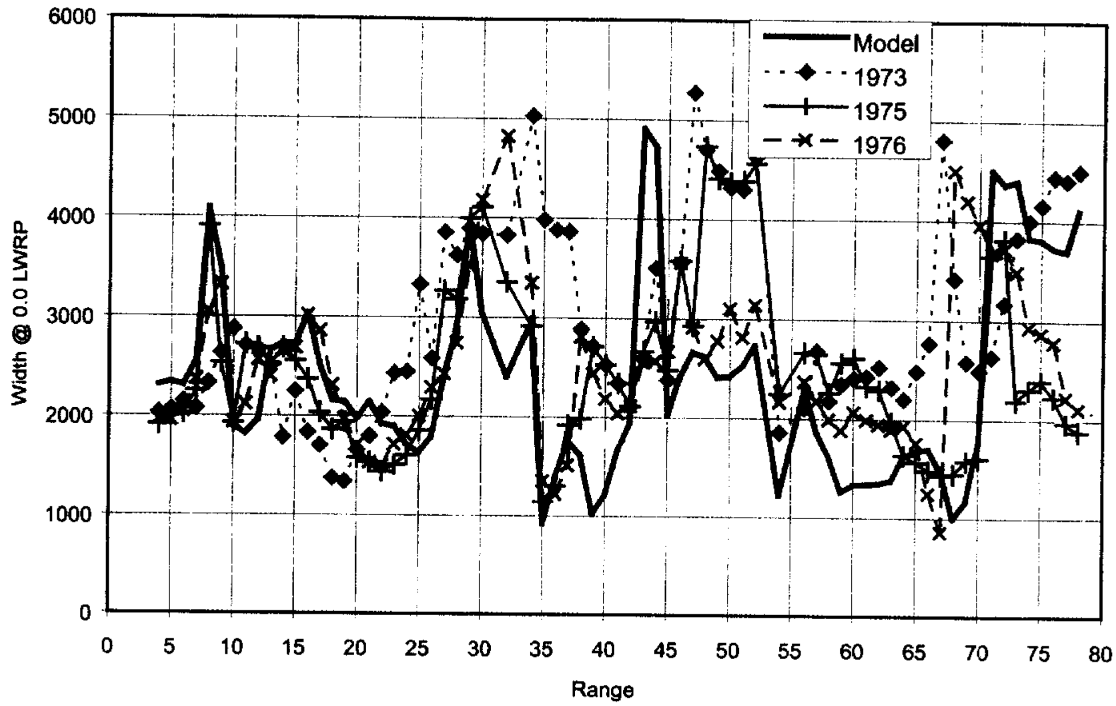

Figure A-20 Width, 1:8000 Kate-Aubrey Micromodel

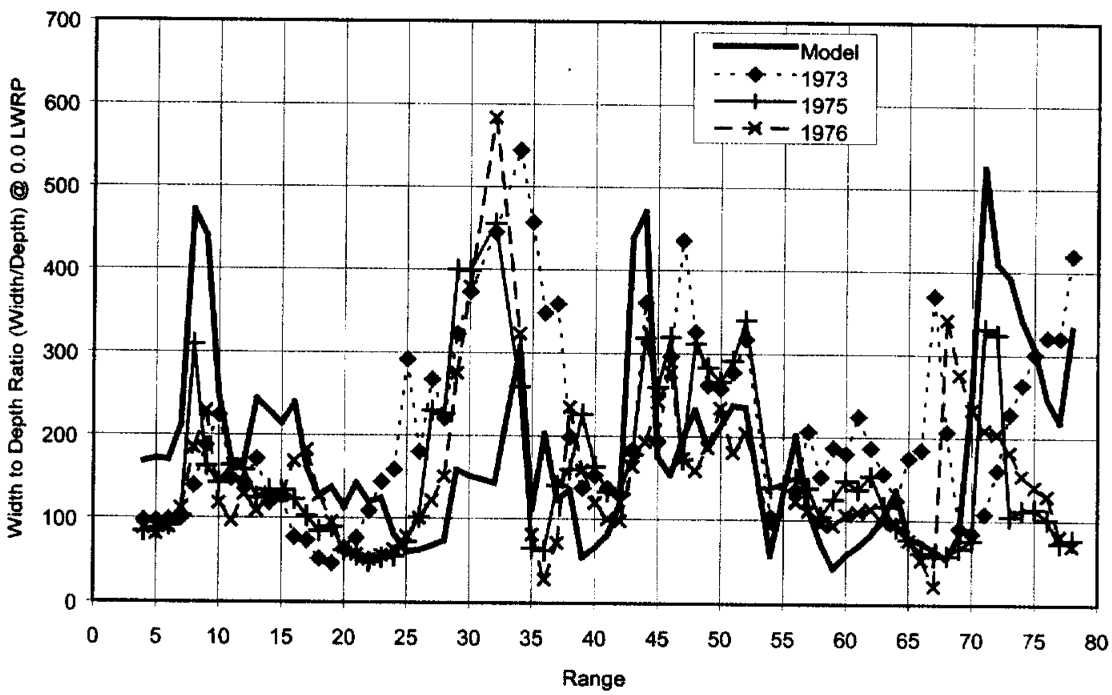

Figure A-21 Width to Depth Ratio, 1:8000 Kate-Aubrey Micromodel

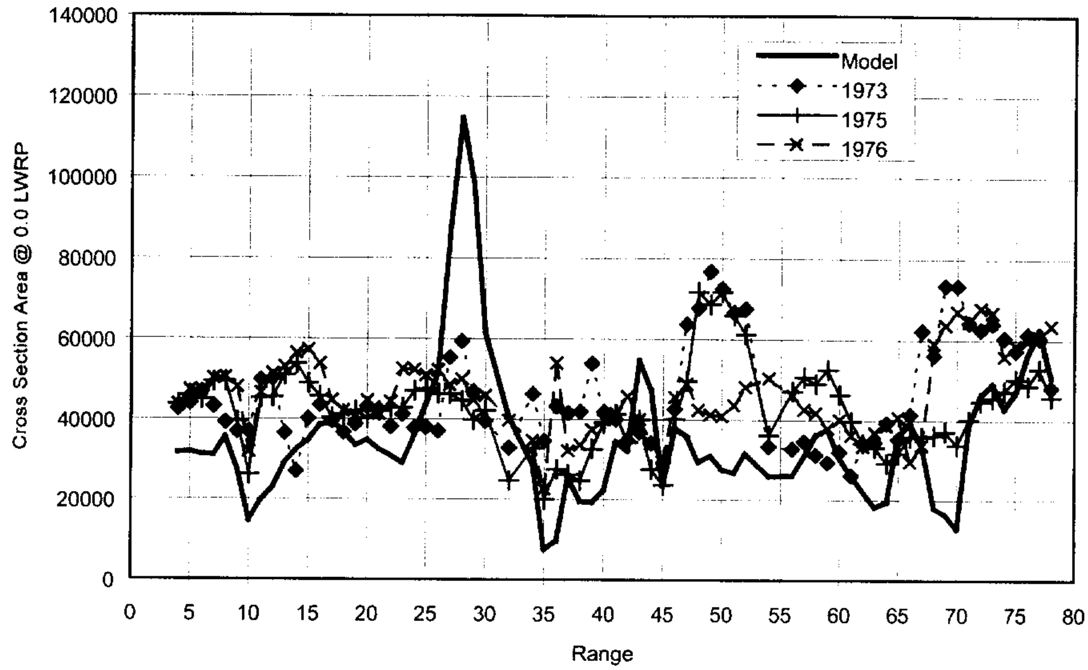

Figure A-22 Area, 1:8000 Kate-Aubrey Micromodel

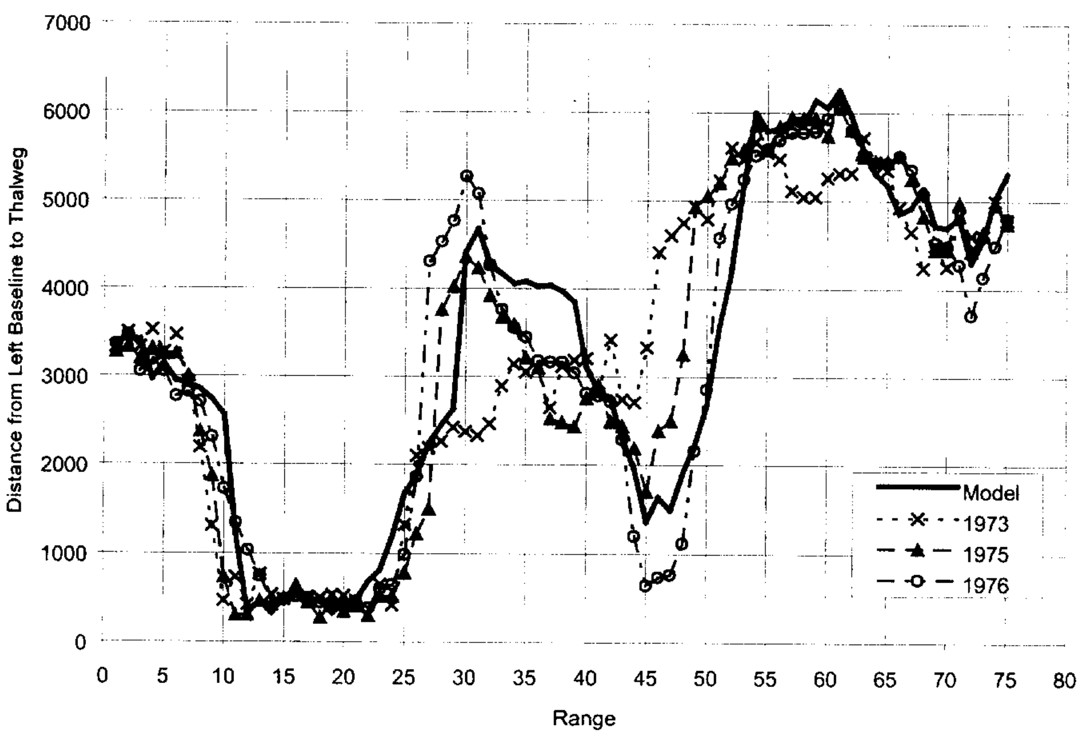

Figure A-23 Thalweg Position, 1:16,000 Kate-Aubrey Micromodel

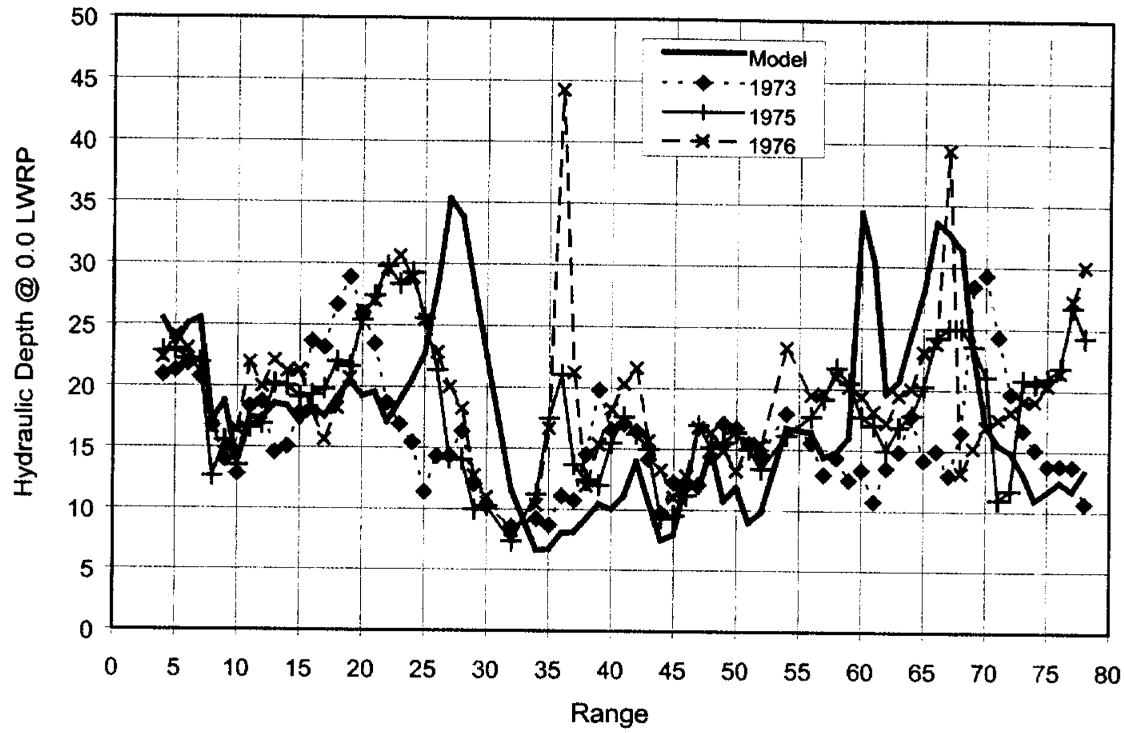

Figure A-24 Hydraulic Depth, 1:16,000 Kate-Aubrey Micromodel

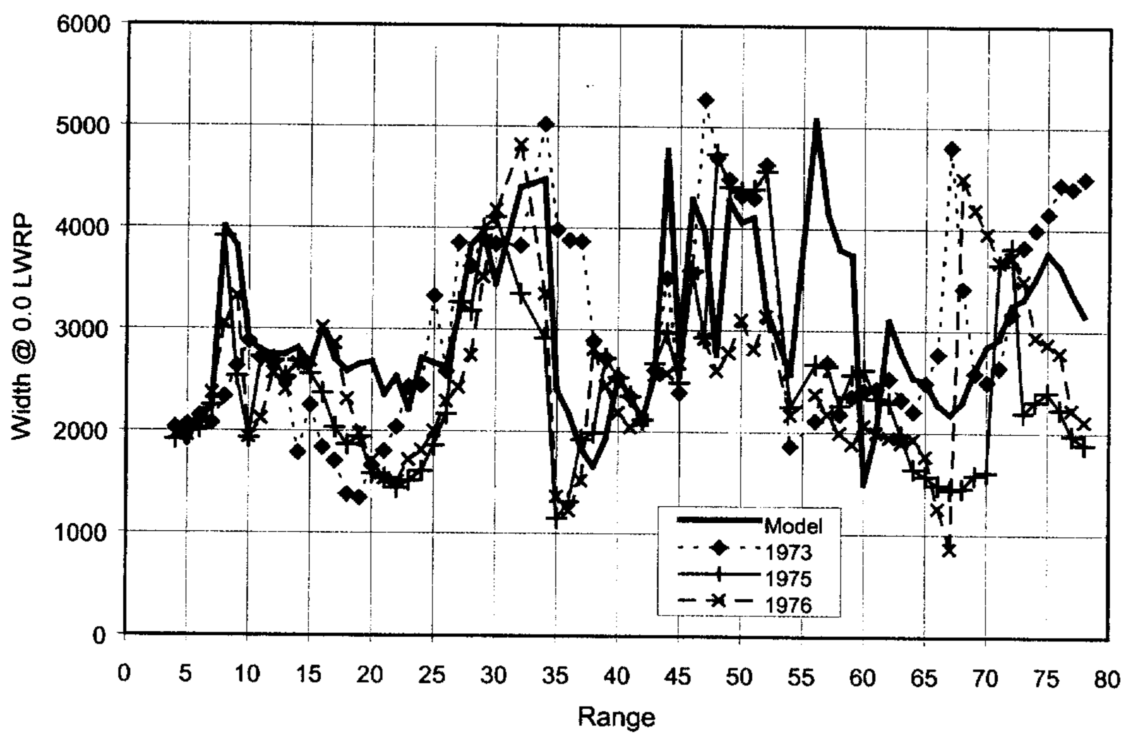

Figure A-25 Width, 1:16,000 Kate-Aubrey Micromodel

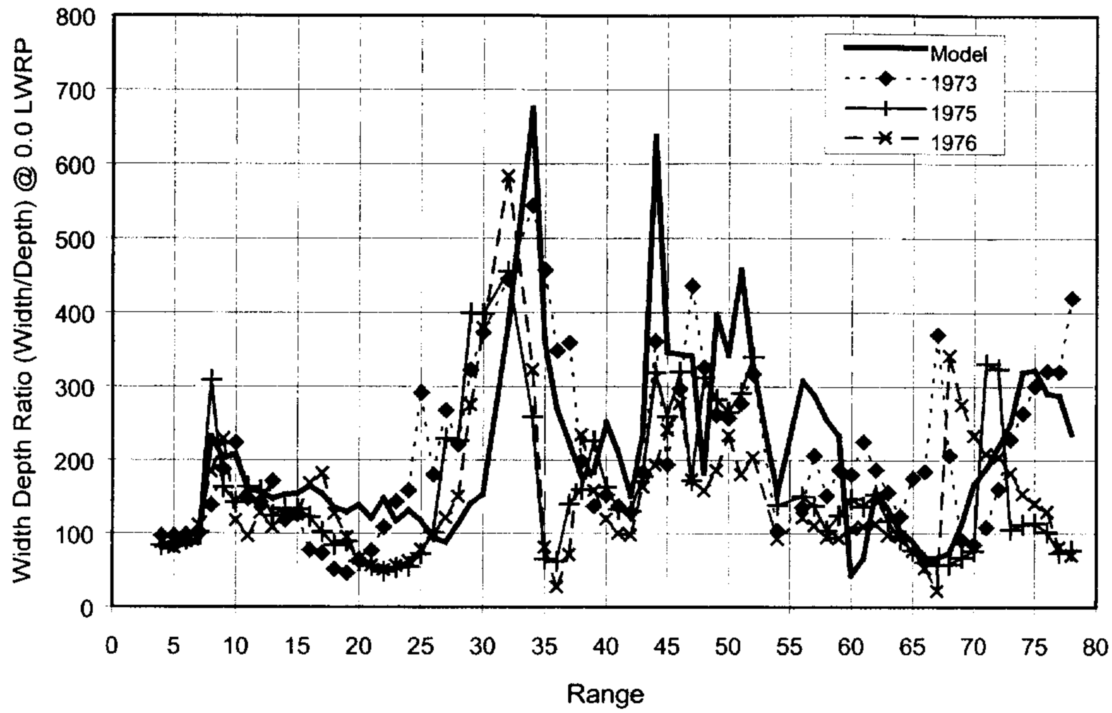

Figure A-26 Width to Depth Ratio, 1:16,000 Kate-Aubrey Micromodel

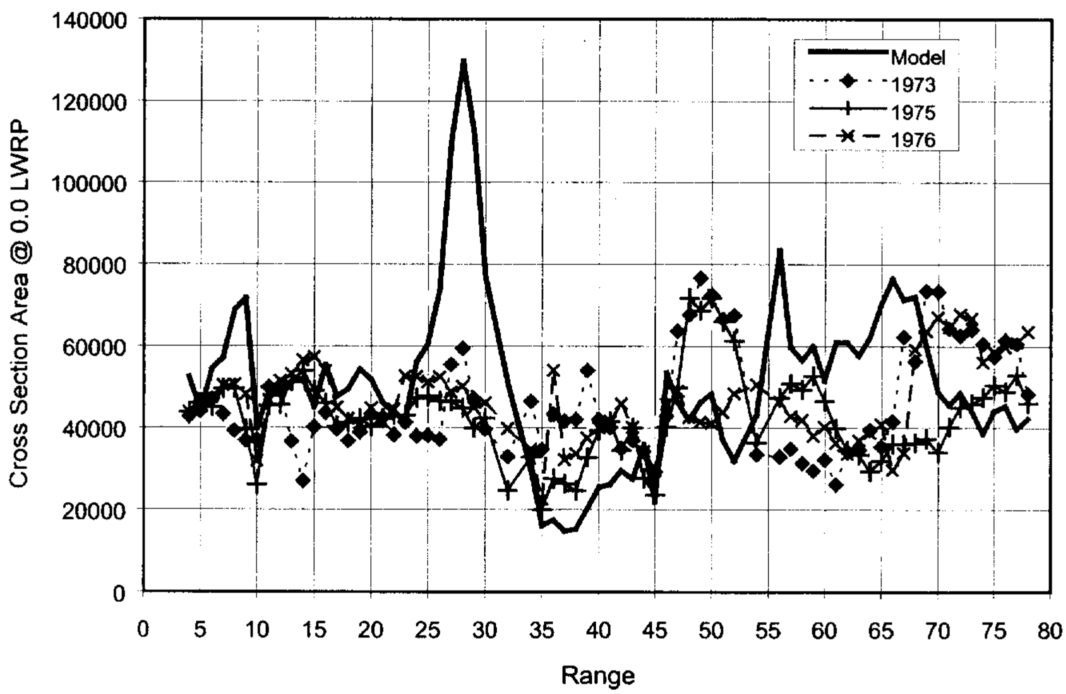

Figure A-27 Area, 1:16,000 Kate-Aubrey Micromodel

A.1.4. Predictive Comparisons.

Given that the physical sediment models included in this investigation relied on a calibration/verification phase to achieve a form of empirical similarity, the ability of a model to reproduce prototype response to a specific modification became a direct measure of the actual similarity between the model and the prototype. In other words, if the model actually reproduced a future response observed in the prototype, then the model behaved in a similar fashion to the prototype. The degree to which a model did (or did not) reproduce detailed features that occurred a prototype was considered as a quantitative measure of the model and prototype agareement (or lack thereof). Additionally, consideration of models at different scales provided a means to assess scale effects on the predictive capability of models and the associated similarity.

Unfortunately, very few cases were found where model recommendations were actually constructed in the prototype. Most cases had only a limited portion of the recommendations implemented. Construction in the Kate-Aubrey reach of the Mississippi River had implemented structural measures very close to model large-scale model recommendations. The improvements for this reach were not built in complete accordance with model recommendations primarily because of adaptations required to fit actual prototype conditions and to accommodate minimal changes for environmental considerations. Modifications required to fit prototype conditions included adjustments in structure lengths and heights to fit changed river bathymetry (from the model condition) at initial construction and a phased construction sequence over a period of years (as opposed to placing all structures in the prototype at once as done in the models). Environmental adaptations involved minor adjustments whereby structure length was adjusted over a very limited range of 90 to 200 feet or notched, 3 to 6 feet vertical and 90 to 200 feet in length, to provide opportunities for side channel development. Figure A-28 shows prototype training structure locations for 1975 (base test) and 1998 (predictive case).

The 1:300 large-scale model study conducted at WES (see Section 3.1.2) had the intended purpose of solving a complex navigation alignment problem. However, a phased construction approach in the prototype resulted in a slightly different structure arrangement than recommended by the WES study. For this reason the WES study was not utilized in assessing model predictive similarities.

Calibration of the two Kate Aubrey micromodels was discussed in the previous section. Predicted response was based on model results obtained for training structures completed in the prototype through 1999 (1999 was the last construction in the reach). Prototype data obtained in 1998 provided the basis for describing prototype conditions for the comparisons. Prototype data for years following 1998 were influenced by a large dredge cut made in 1999 (Figure A-29 and Figure A-30). However, the large quantity of dredging that occurred during the late 1980's must also be considered in assessing prototype response between the calibration period, mid-1970's, and current prototype conditions.

Although construction in the reach ended in 1999, modifications following 1998 had an insignificant effect on the overall reach configuration. Therefore, 1998 survey data were used in the evaluation of model predictive capability. Prototype bathymetry in the Kate-Aubrey reach for 1998 is shown in Figure A-31. Predicted model bathymetric maps for the 1:8,000 and 1:16,000 micromodels are shown in Figure A-32 and Figure A-33, respectively.

Plots of thalweg position, hydraulic depth, width, width to depth ratio, and cross-section area are shown in Figure A-34, Figure A-35, Figure A-36, Figure A-37 and A-38, respectively, for the 1998 prototype, for the 1:8,000 micromodel, and the 1:16,000 micromodel surveys. Hydraulic depth, width, width to depth ratio, and cross-section area values for the morphologic parameter graphs were calculated using a water surface elevation of 0.0 low water reference plane.

Table A-4 provides a summary of observations made from plotted morphologic parameters in the 1:8,000 micromodel analysis. Table A-5 provides summary descriptions of morphologic parameter plots for the 1:16,000 micromodel.

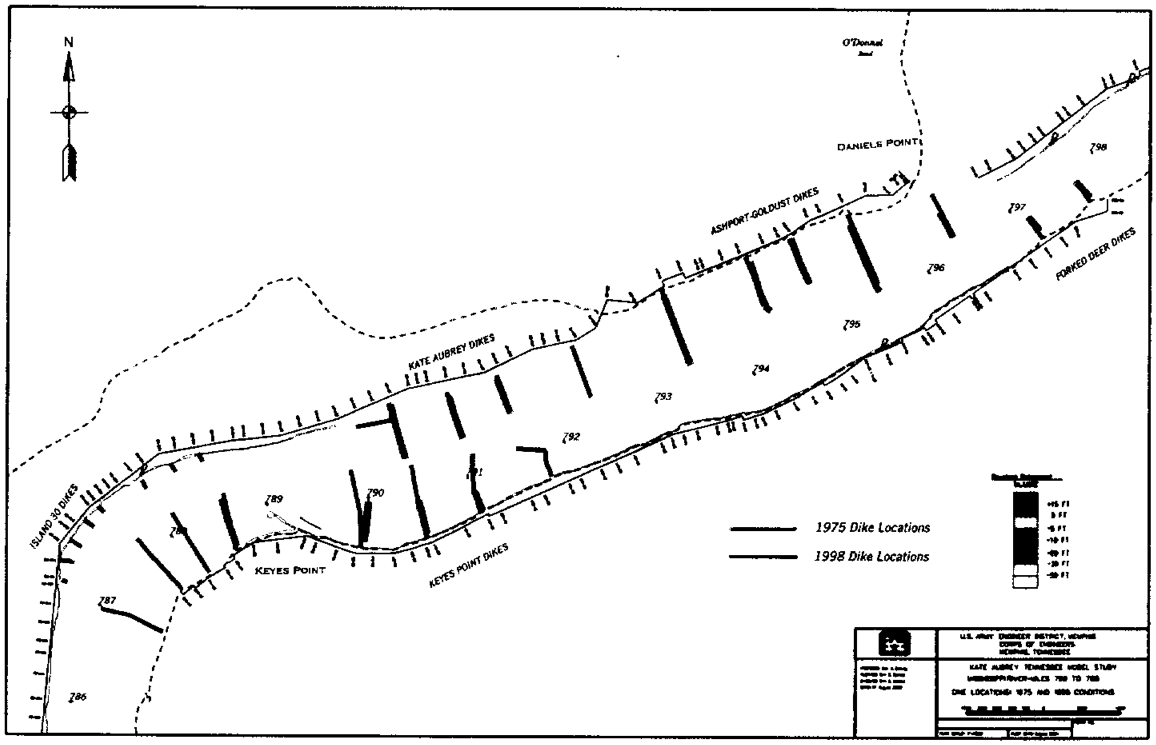

Figure A-28 Dike Locations, Kate Aubrey Reach

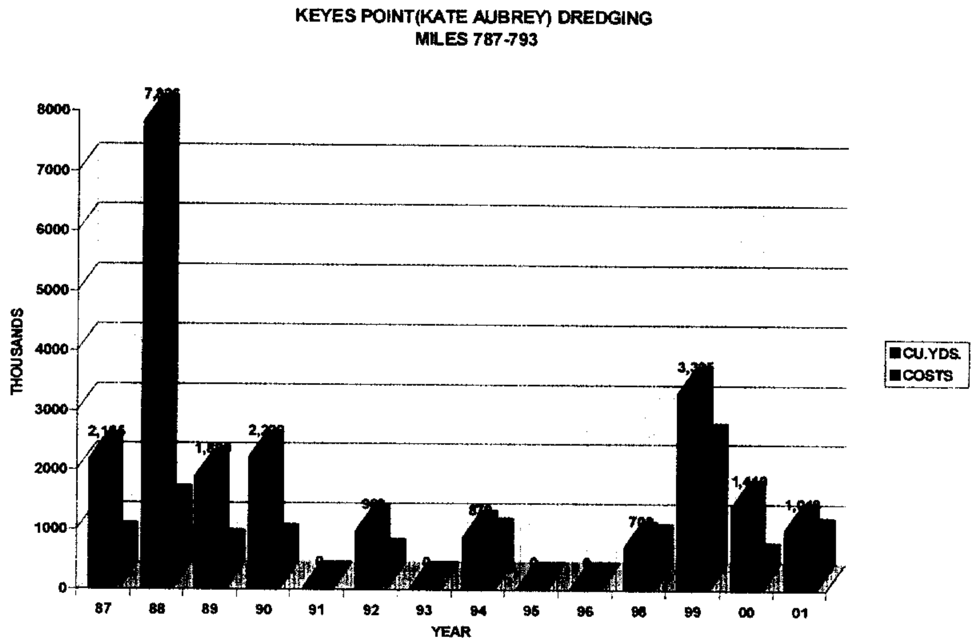

Figure A-29 Kate Aubrey Dredging Amounts and Costs

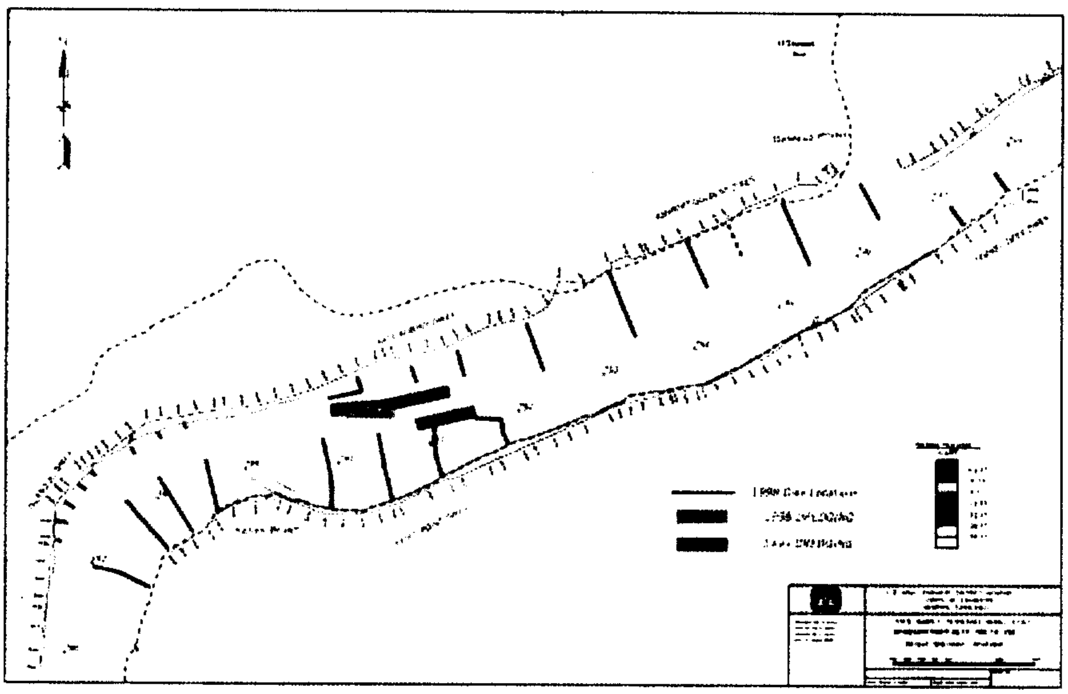

Figure A-30 Kate Aubrey Dredge Locations by Year

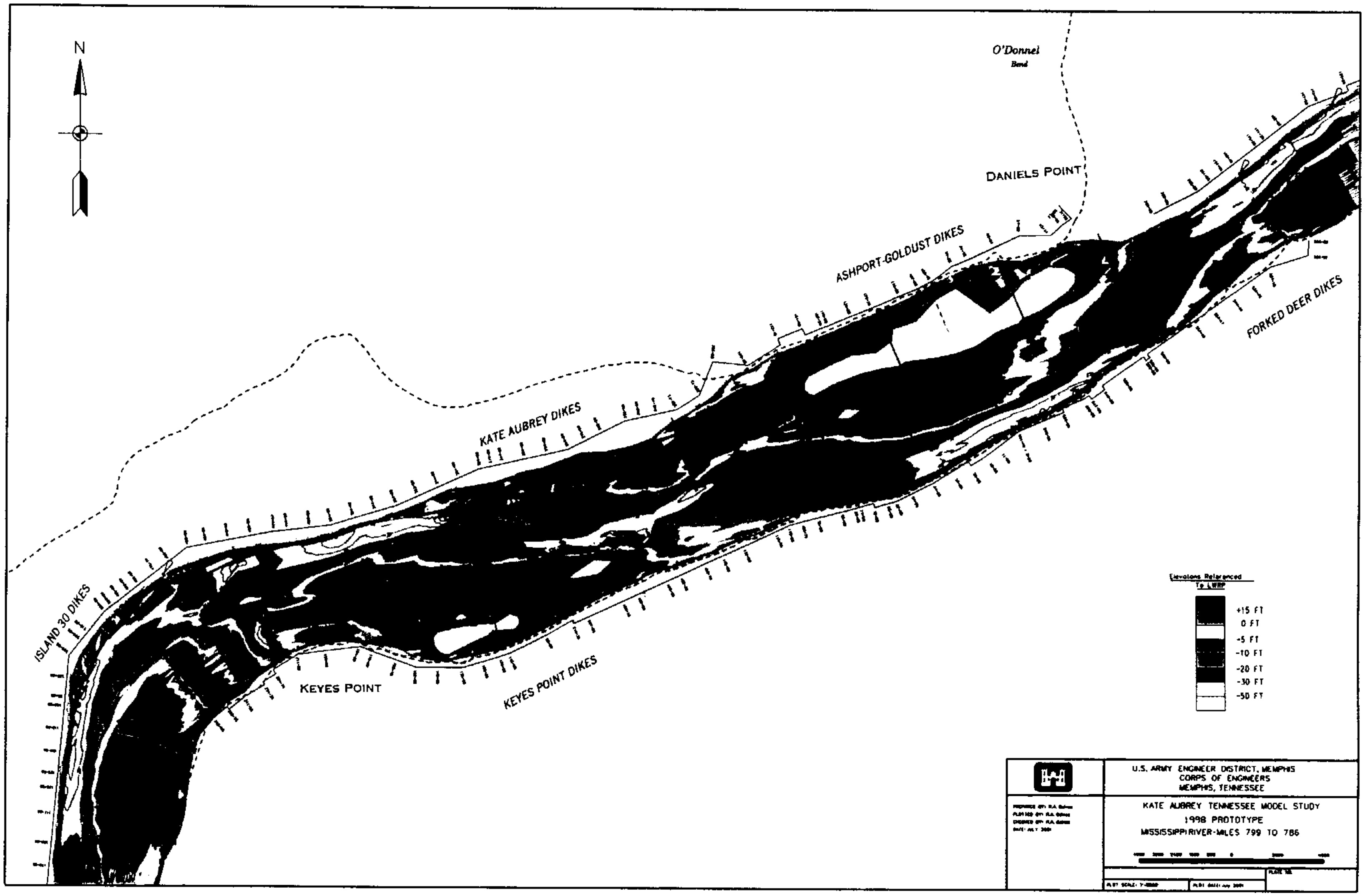

Figure A-31 1998 Prototype Bathymetry, Kate-Aubrey Reach

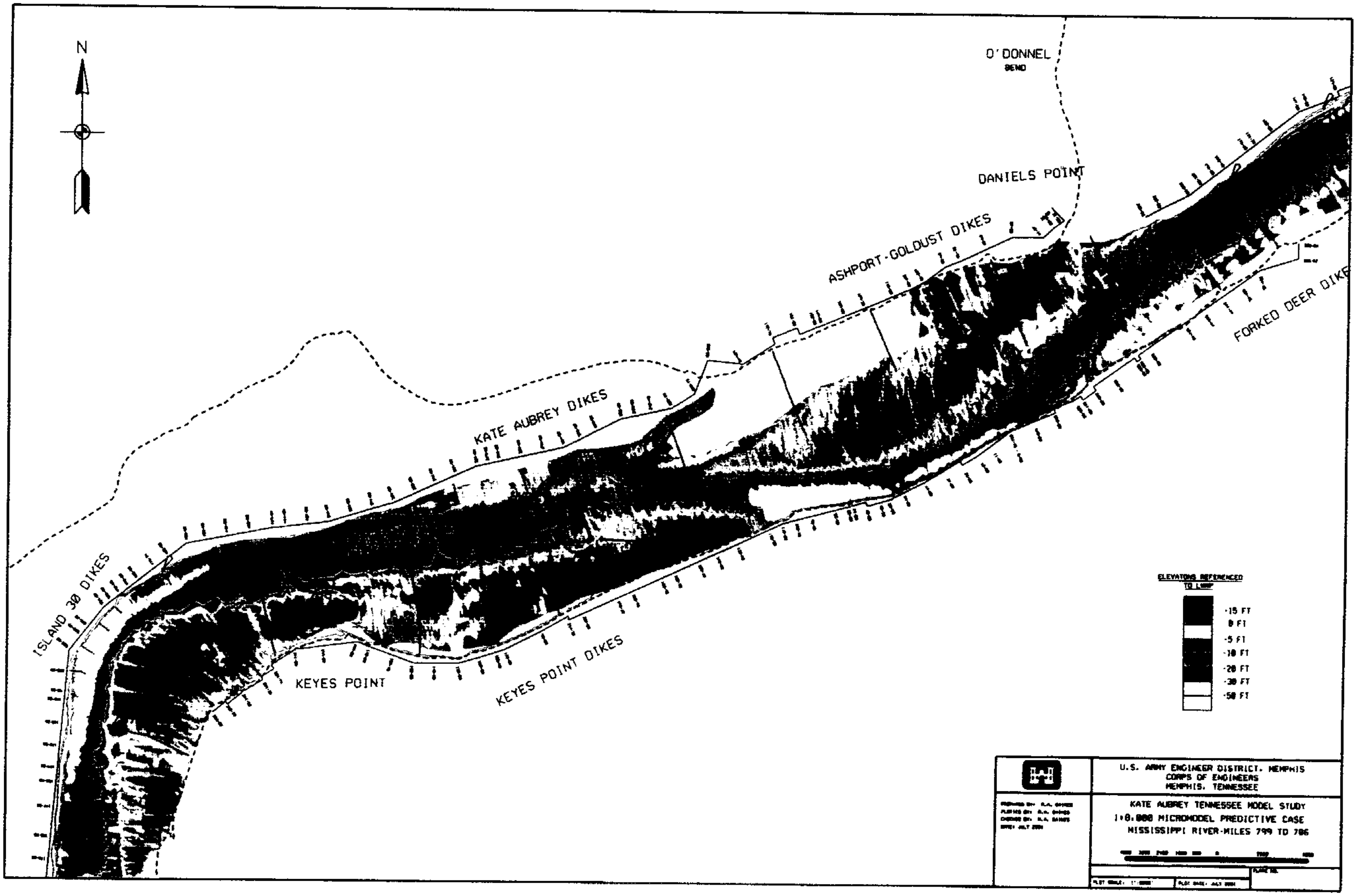

Figure A-32 Predictive Model Bathymetry, Kate-Aubrey 1:8,000 Micromodel

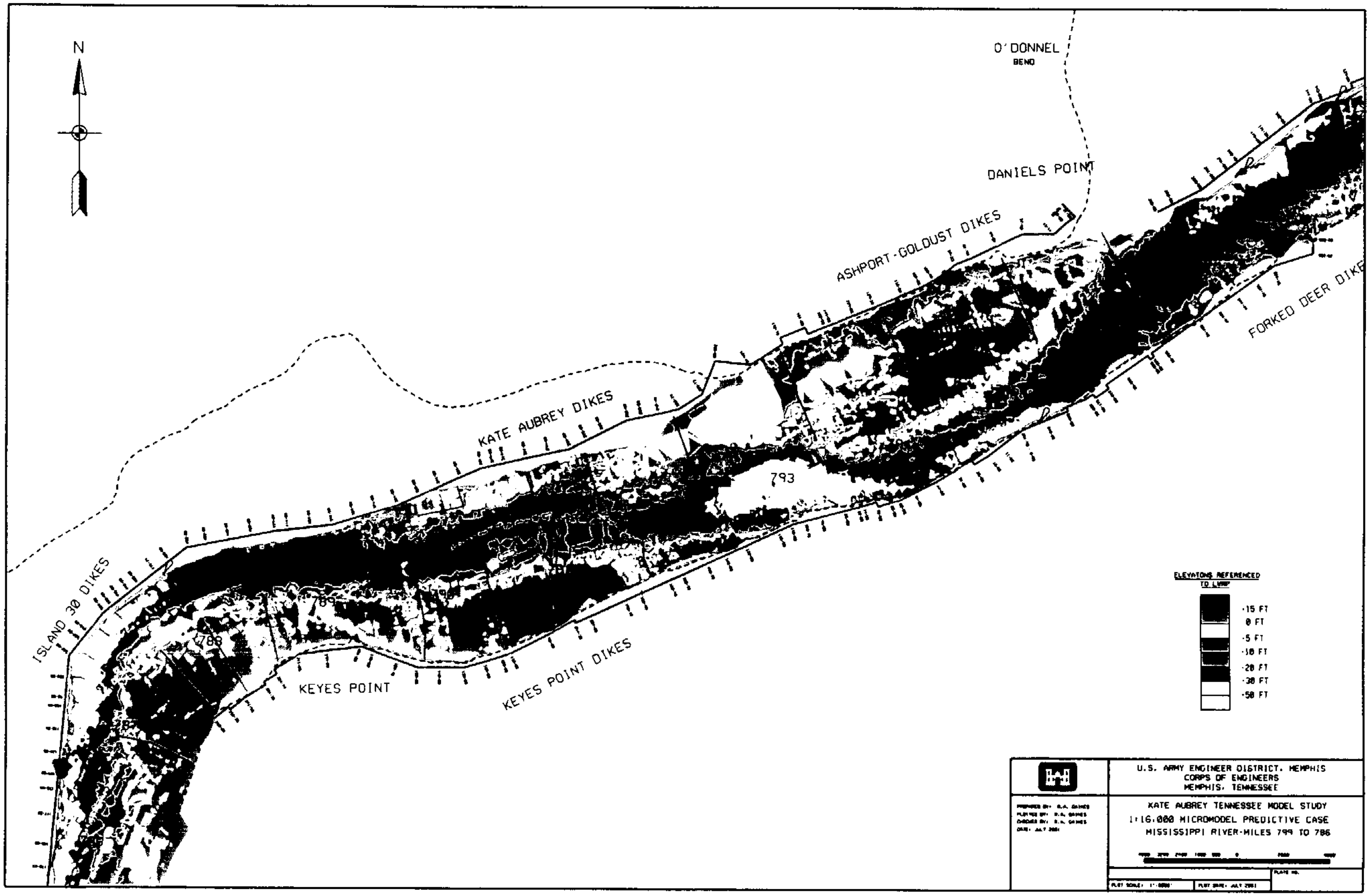

Figure A-33 Predictive Model Bathymetry, Kate-Aubrey 1:16,000 Micromodel

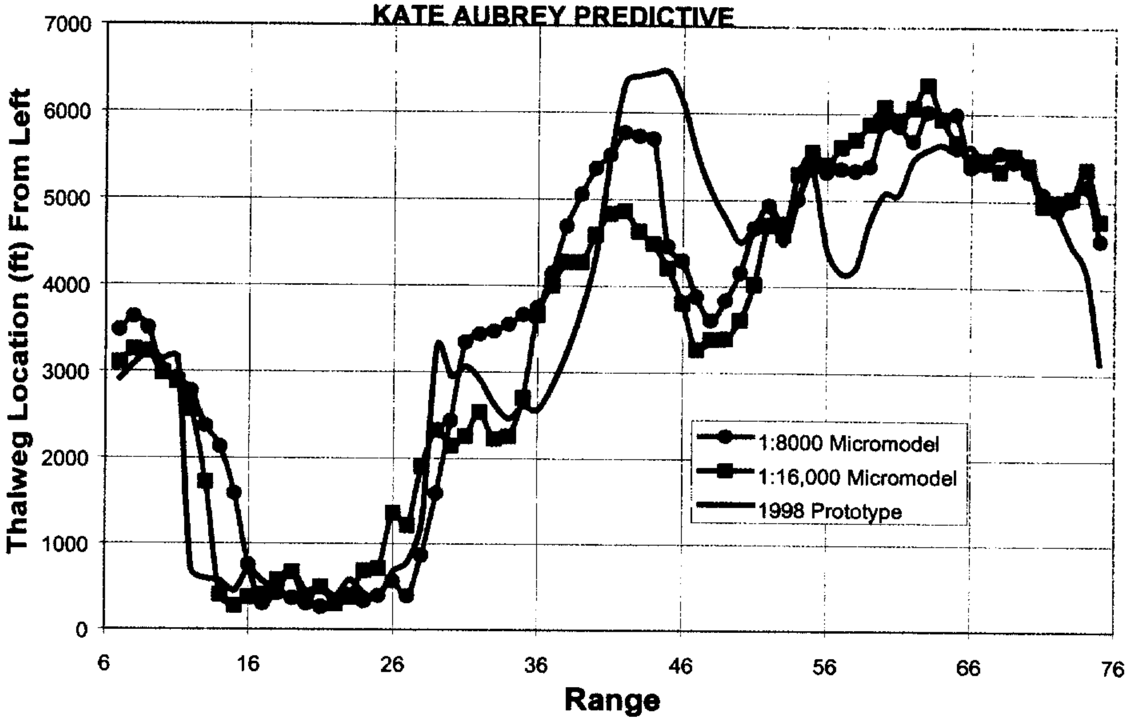

Figure A-34 Thalweg Position Predictive Kate-Aubrey Model Case

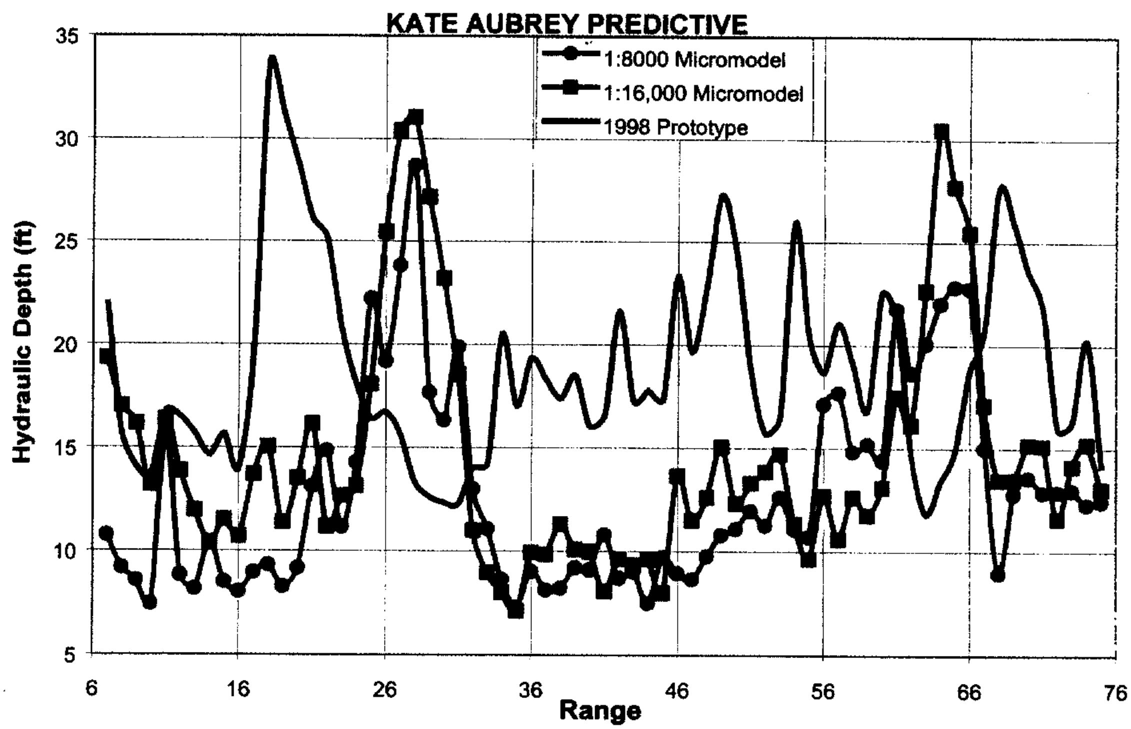

Figure A-35 Hydraulic Depth Predictive Kate-Aubrey Model Case

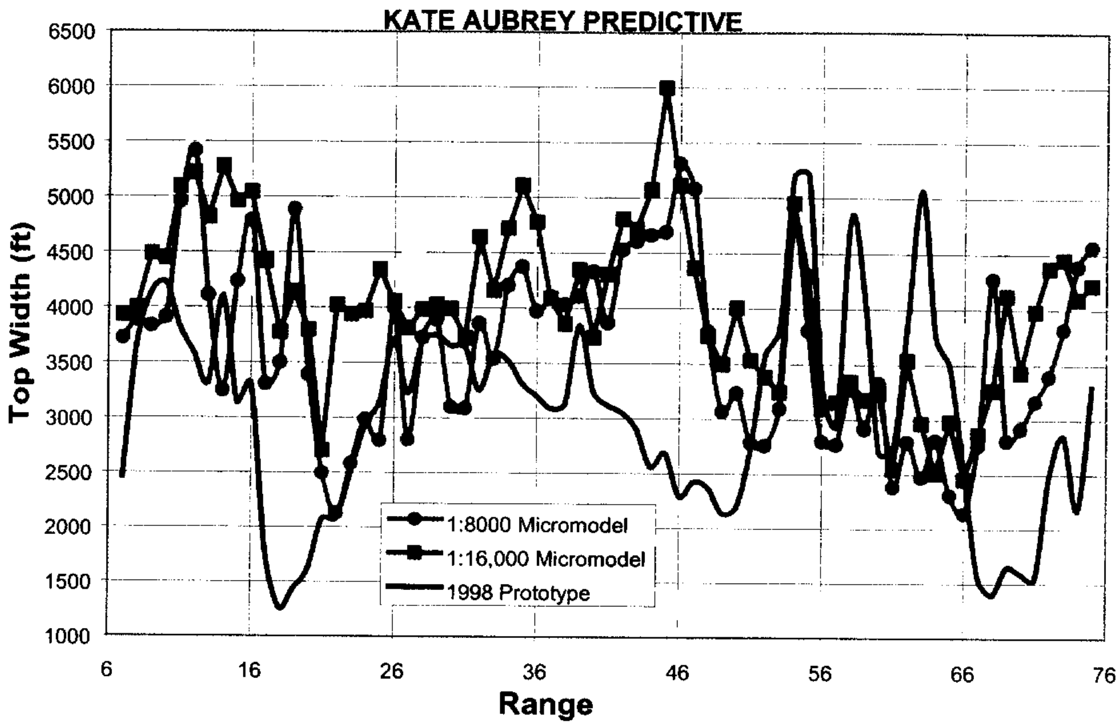

Figure A-36 Width Predictive Kate-Aubrey Model Case

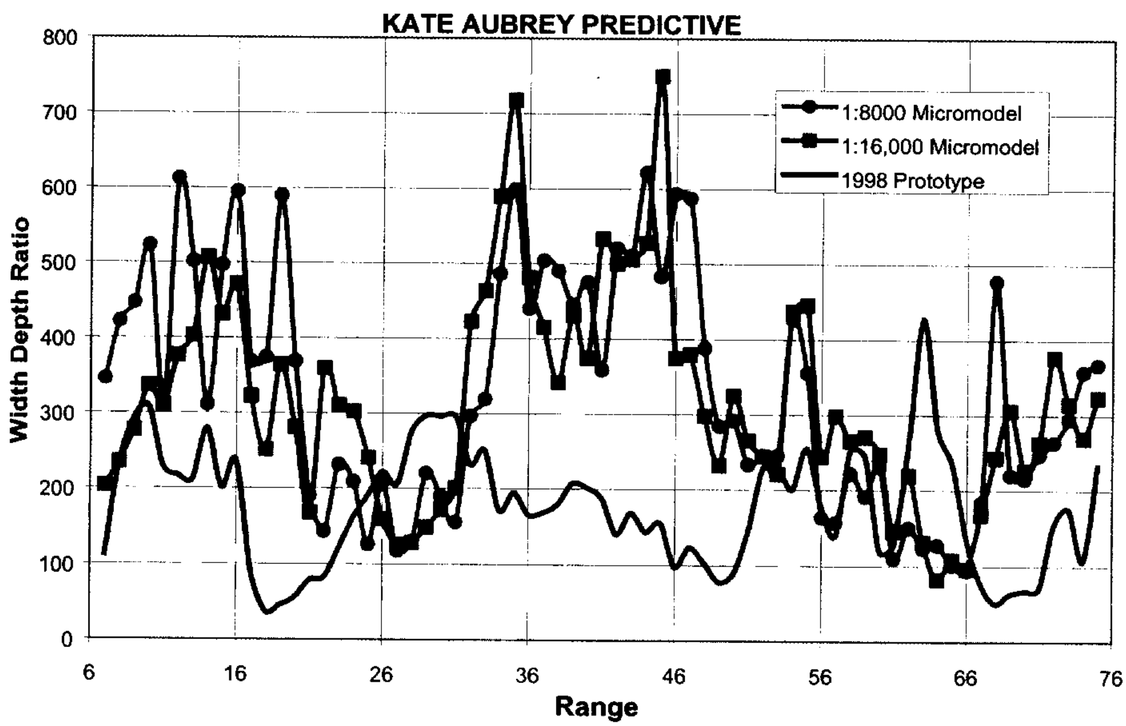

Figure A-37 Width/Depth Ratio Predictive Kate-Aubrey Model Case

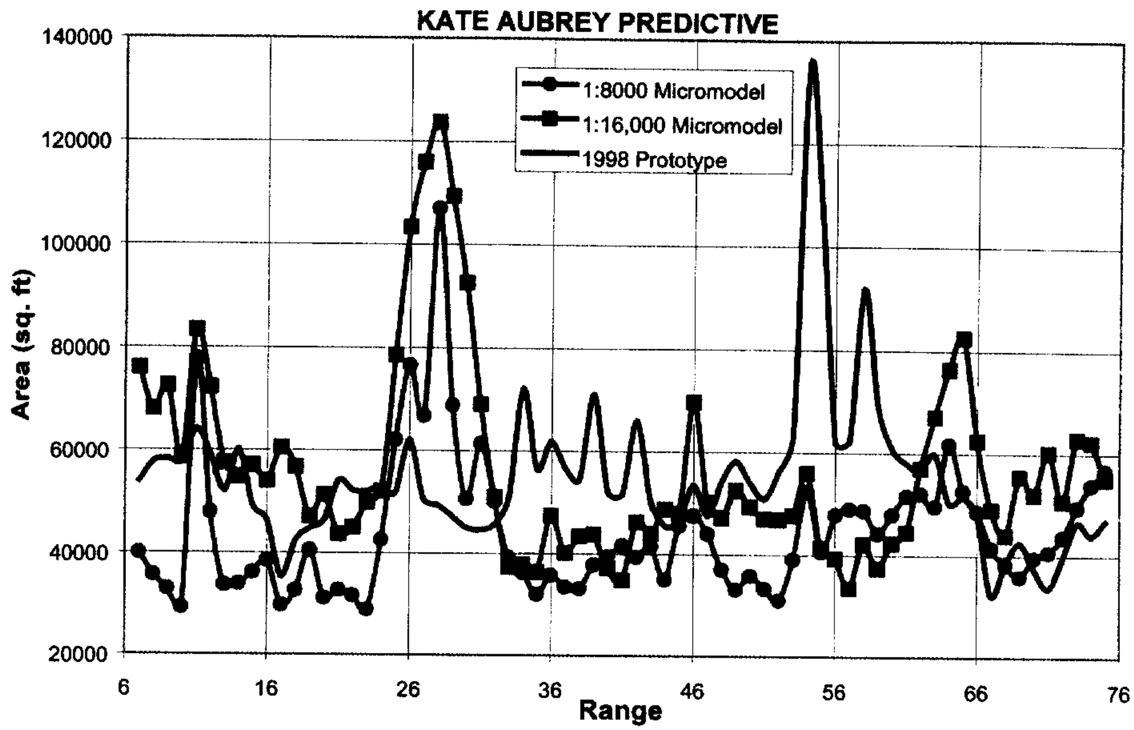

Figure A-38 Area Predictive Kate-Aubrey Model Case

Table A-4 Morphologic Parameter Assessment, 1:8,000 Kate-Aubrey Predictive Micromodel

Morphologic Parameter	Notes
Thalweg Position	Agreement between model and prototype fair except R44-50 and R55-65
Hydraulic Depth at 0.0 LWRP	model under predicts depth by approximately 5.0 feet
Width at 0.0 LWRP	Model over predicts width
Width/Depth Ratio at 0.0 LWRP	Ratio over predicted
Area at 0.0 LWRP	Area under predicted by model, esp. R52-63; Area over predicted R28-30

Table A-5 Morphologic Parameter Assessment, 1:16,000 Kate-Aubrey Predictive Micromodel

Morphologic Parameter	Notes
Thalweg Position	Agreement between model and prototype fair except R40-50 and R55-65.
Hydraulic Depth at 0.0 LWRP	Model under predicts depth
Width at 0.0 LWRP	Model over predicts width
Width/Depth Ratio at 0.0 LWRP	Ratio over predicted
Area at 0.0 LWRP	Area under predicted by model, esp. R52-62; area over predicted R25-32

A.1.5. Summary of Kate-Aubrey Model Analysis.

Basic interpretation of model results in previous sections was based on visual inspection of bathymetry snd parameter plots. Parameter values obtained by averaging and weighting techniques are shown in Table A-6. Table A-6 presents reach morphologic parameter values calculated by two methods: arithmetic average and reach weighted. Table A-7 lists percent differences between model and prototype values by each calculation method for each of the Kate Aubrey examples.

Although construction of training structures in the reach were similar to the reccomended model alternative, dredging within the reach (Figure A-29) was not simulated by the model. The locations of dredge cuts made prior to about 1990 are unknown.

A.2. Bathymetric Repeatability

An important aspect of loose-bed physical sediment models pertains to the ability of a model to reproduce consistent, or nearly so, bathymetry between successive runs. Ideally, if model boundary conditions (input hydrograph, slopes, sediment loadings, etc.) remain constant between successive runs, then the expectation would be to produce the same bathymetry for each run, there would be a unique model solution. Although the micromodel operates with an equilibrium bed concept where sediment is recirculated, the stochastic nature of sediment transport produces non-unique model bathymetry for a consistent hydrographic input. The prototype exhibits variable bathymetry primarily in v response to variable inputs of discharge and sediment inflow, but even consistent flow conditions[1] result in an ever changing bed configuration in the prototype.

Repetition of model bathymetry is considered by evaluating multiple bed surveys obtained after operating the calibrated model through the same series of inflow hydrographs.

A.2.1. Kate-Aubrey 1:16,000 Micromodel. The Kate-Aubrey 1:16,000 micromodel was subjected to several repetitive hydrograph cycles in order to assess the ability of the model to reproduce consistent bathymetric data. In all, five repetitions were completed. The surveys of the 1:16,000 micromodel were taken after model calibration. Each repetition included operating the model for a number of hydrograph cycles, stopping the model at the peak of the hydrograph cycle, allowing the model to slowly drain, and then surveying the bathymetry. The number of cycles between repetitions varied as shown in Table A-8.

[1] Consistent boundary conditions in the prototype may be approximated for short time-intervals during extended low flow periods.

Table A-6 Reach Morphologic Parameter Values by Two Methods

Reach Morphologic Parameter Values - Kate Aubrey Reach, Mississippi River								
Survey	Case	Method for Determining Reach Value	Number of Ranges	Area (sq. ft.)	Hydraulic Depth (ft.)	Width (ft.)	Width/ Depth	Thalweg Position[1]
1:300 Model	Verification	Arithmetic	28	26501	13.6	2107	211	na
		Reach Weighted		26195	12.4	2108	170	na
1975 Prototype		Arithmetic	28	33394	13.7	2696	252	na
		Reach Weighted		34116	12.1	2823	234	na
1976 Prototype		Arithmetic	28	38064	16.6	2644	227	na
		Reach Weighted		38058	14.2	2687	190	na
1:8,000 Micromodel	Calibration	Arithmetic	71	35540	15.6	2385	182	na
		Reach Weighted		35993	15.2	2375	157	na
1973 Prototype		Arithmetic	71	45839	16.3	2983	209	na
		Reach Weighted		45937	15.3	3010	197	na
1975 Prototype		Arithmetic	71	42688	18.4	2488	159	na
		Reach Weighted		42333	16.6	2556	154	na
1976 Prototype		Arithmetic	71	46372	19.8	2509	148	na
		Reach Weighted		46493	17.9	2603	146	na
1:16,000 Micromodel	Calibration	Arithmetic	75	51034	17.5	3030	213	na
		Reach Weighted		51490	16.9	3041	180	na
1973 Prototype		Arithmetic	75	45054	16.1	2973	213	na
		Reach Weighted		45482	15.3	2981	195	na
1975 Prototype		Arithmetic	75	42323	18.1	2508	164	na
		Reach Weighted		42199	16.6	2540	153	na
1976 Prototype		Arithmetic	75	46065	19.5	2552	157	na
		Reach Weighted		46206	17.8	2596	146	na
1:8,000 Micromodel	Predictive	Arithmetic	78	36836	16.1	2366	173	na
		Reach Weighted		36689	15.5	2364	152	na
1998 Prototype		Arithmetic	78	48761	21.9	2326	117	na
		Reach Weighted		48539	20.6	2352	114	na
2001 Prototype		Arithmetic	78	47942	21.2	2326	117	na
		Reach Weighted		47927	20.4	2353	116	na
1:16,000 Micromodel	Predictive	Arithmetic	78	49825	19.3	2604	150	na
		Reach Weighted		50248	19.2	2616	136	na
1998 Prototype		Arithmetic	78	48761	21.9	2326	117	na
		Reach Weighted		48539	20.6	2352	114	na
2001 Prototype		Arithmetic	78	47942	21.2	2326	117	na
		Reach Weighted		47927	20.4	2353	116	na

[1] Thalweg position is measured relative to an arbitrary point at each Range. Values of average or reach weighted Thalweg Position , therefore, provide no meaningful description of thalweg behavior in the reach.

Table A-7 Differences Between Model and Prototype, Case Study Examples

Summary of Differences[1] in Morphologic Parameter Values by Various Methods
Kate Aubrey Reach, Mississippi River

Survey	Method for Determining Reach Value	Number of Ranges	Percent Difference between Model Value and Individual Survey				
			Area (sq. ft.)	Hydraulic Depth (ft.)	Width (ft.)	Width/ Depth	Thalweg Position [2]
1:300 Model - Verification							
1975 Prototype	Arithmetic	28	-20.6	-0.3	-21.9	-16.0	na
	Reach Wtd.		-23.2	2.8	-25.3	-27.4	na
1976 Prototype	Arithmetic	28	-30.4	-17.9	-20.3	-6.9	na
	Reach Wtd.		-31.2	-12.3	-21.5	-10.5	na
1:8,000 Micromodel - Base Calibration							
1973 Prototype	Arithmetic	71	-22.5	-3.9	-20.1	-12.8	na
	Reach Wtd.		-21.6	-0.7	-21.1	-20.6	na
1975 Prototype	Arithmetic	71	-16.7	-14.8	-4.2	14.6	na
	Reach Wtd.		-15.0	-8.5	-7.1	1.5	na
1976 Prototype	Arithmetic	71	-23.4	-21.1	-5.0	23.4	na
	Reach Wtd.		-22.6	-15.2	-8.8	7.5	na
1:16,000 Micromodel - Base Calibration							
1973 Prototype	Arithmetic	75	13.3	8.8	1.9	0.1	na
	Reach Wtd.		13.2	11.0	2.0	-8.1	na
1975 Prototype	Arithmetic	75	20.6	-3.2	20.8	30.1	na
	Reach Wtd.		22.0	1.9	19.7	17.5	na
1976 Prototype	Arithmetic	75	10.8	-10.4	18.7	35.4	na
	Reach Wtd.		11.4	-4.9	17.2	23.2	na
1:8,000 Micromodel Predictive Case							
1998 Prototype	Arithmetic	78	-24.5	-26.3	1.7	48.1	na
	Reach Wtd.		-24.4	-24.8	0.5	33.6	na
2001 Prototype	Arithmetic	78	-23.2	-23.8	1.7	47.1	na
	Reach Wtd.		-23.4	-23.8	0.5	31.9	na
1:16,000 Micromodel - Predictive Case							
1998 Prototype	Arithmetic	78	2.2	-11.8	11.9	28.7	na
	Reach Wtd.		3.5	-6.9	11.2	19.4	na
2001 Prototype	Arithmetic	78	3.9	-8.8	11.9	27.8	na
	Reach Wtd.		4.8	-5.7	11.2	17.8	na

[1] Differences calculated between Model and prototype parameter values expressed as a percent and are not indicative of model accuracy.

[2] Thalweg differences provide only a relative expression of agreement, model to prototype, for measurements taken from a common baseline. Therefore, differences for Thalweg Position were not computed.

na = Average and Weighted Thalweg Position not considered representative of Reach conditions.

Table A-8 Number of Hydrograph Cycles Between Surveys

Survey	Number of Hydrograph Cycles Between Surveys[2]
022301d	Calibration - Base Test
022701a	3
022701b	5
022701c	21
022801a	5

Variability between successive model runs is presented by cross-section comparison plots (Figures A-39 to A-45) and by a plot of hydraulic depth at 0.0 LWRP over the model length (Figure A-46). Cross-section plots provide a description of how the channel geometry is replicated when the model is operated with consistent, variable hydrographs for each run. Plots of hydraulic depth for all ranges in the model provide a description of how depth varies over the length of the model for each bathymetric survey.

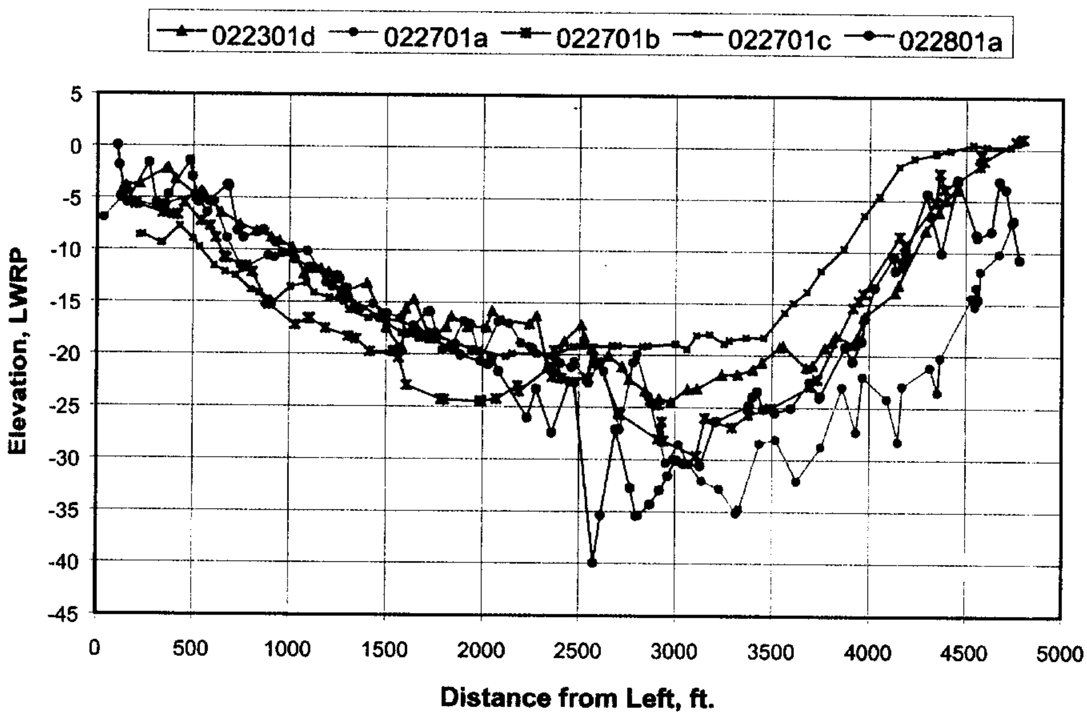

Figure A-39 Repeatability of Model Bathymetry, Kate-Aubrey Range 10

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[2] Cycle length in the 1:16,000 micromodel was 1.8 minutes per cycle.

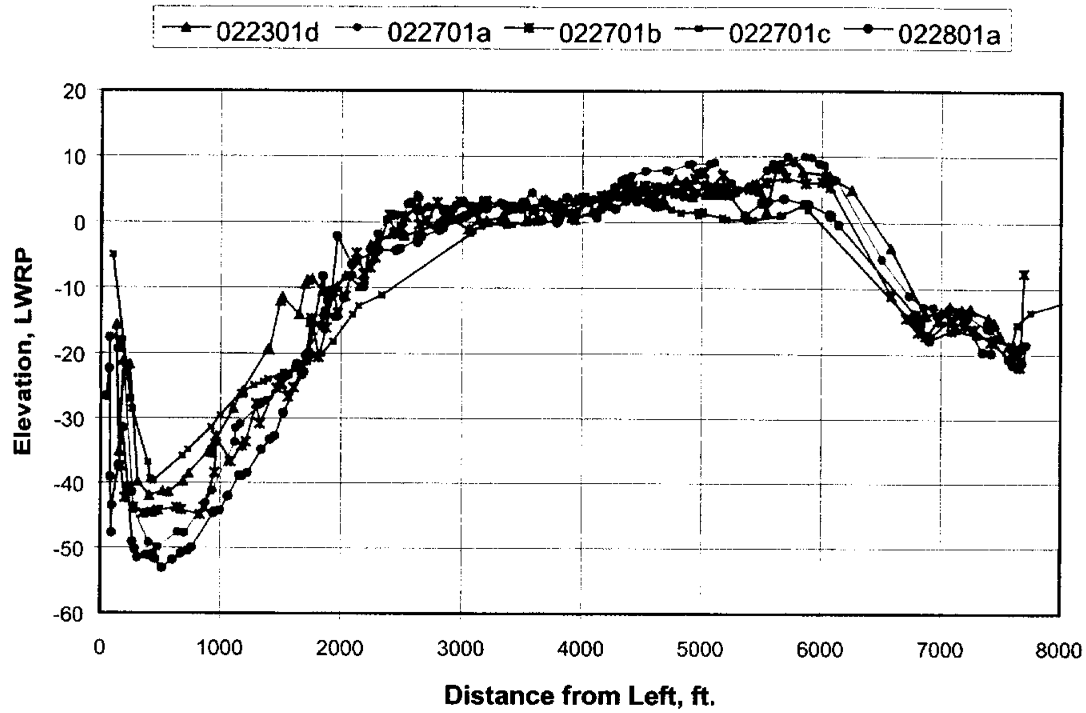

Figure A-40 Repeatability of Model Bathymetry, Kate-Aubrey Range 20

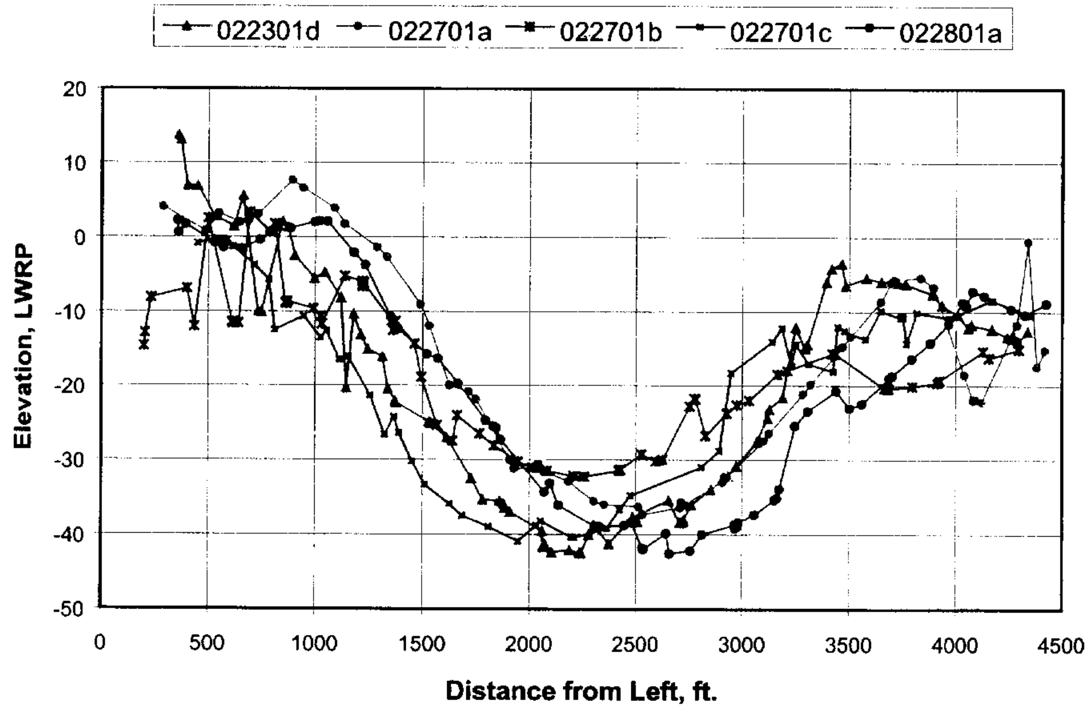

Figure A-41 Repeatability of Model Bathymetry, Kate-Aubrey Range 30

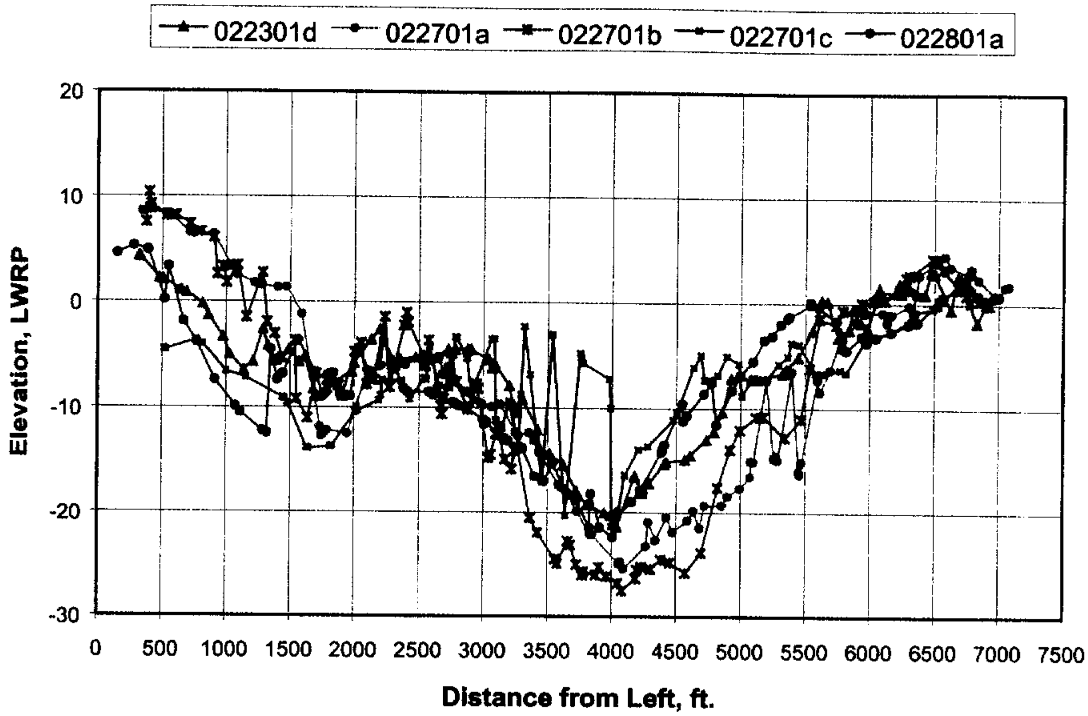

Figure A-42 Repeatability of Model Bathymetry, Kate-Aubrey Range 40

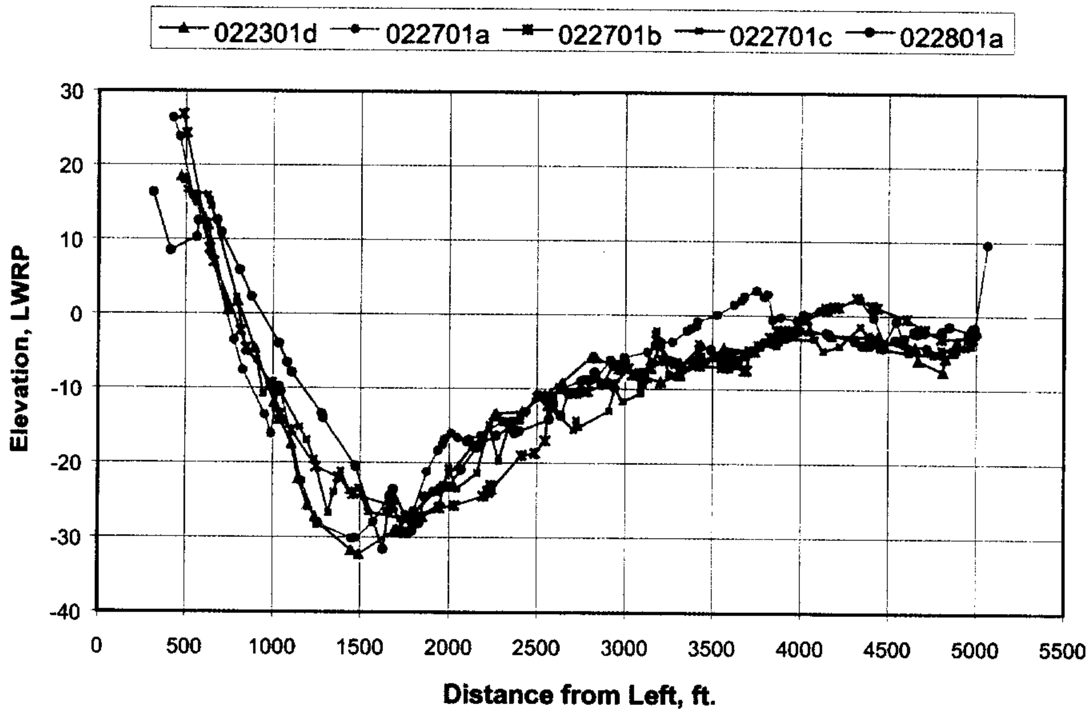

Figure A-43 Repeatability of Model Bathymetry, Kate-Aubrey Range 50

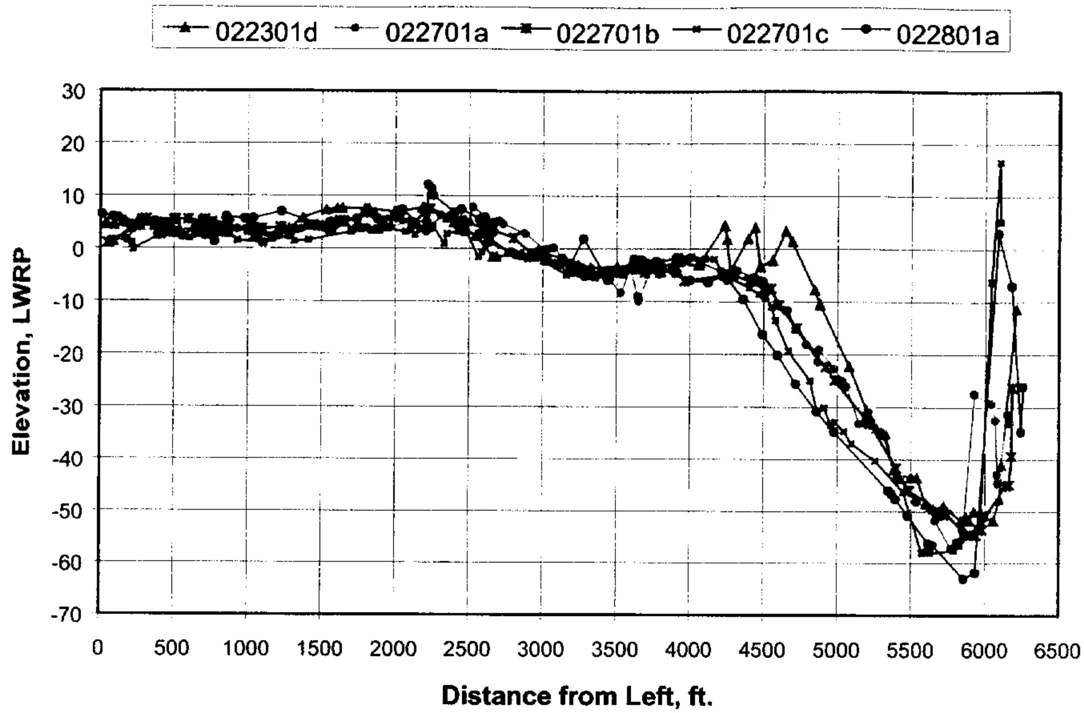

Figure A-44 Repeatability of Model Bathymetry, Kate-Aubrey Range 60

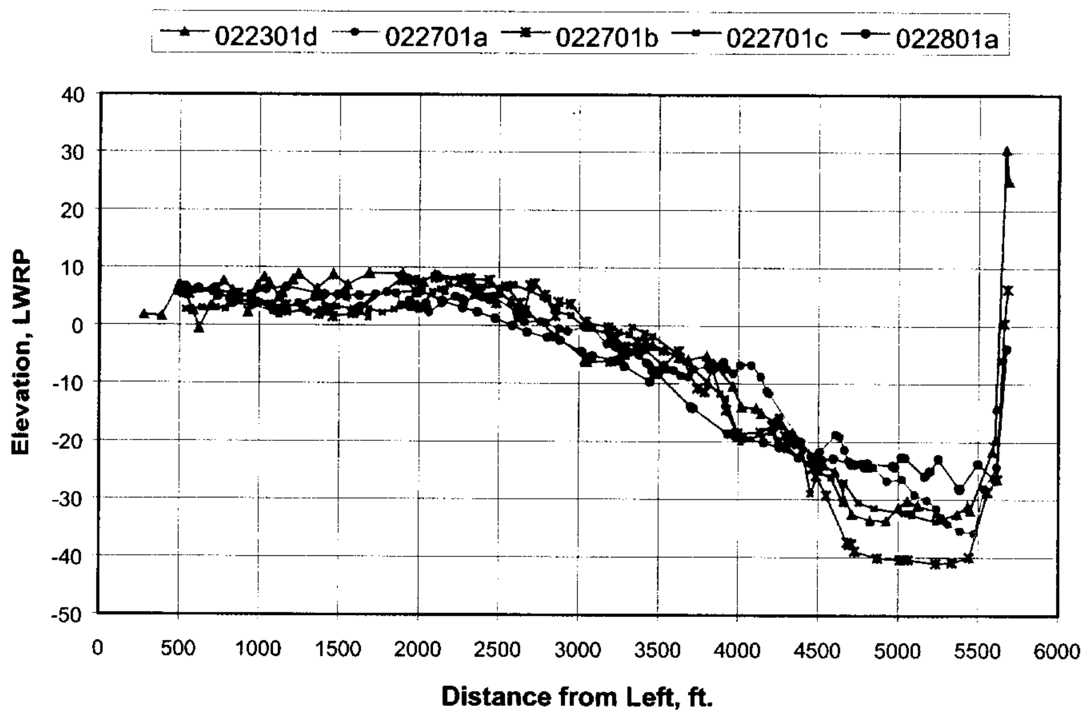

Figure A-45 Repeatability of Model Bathymetry, Kate-Aubrey Range 70

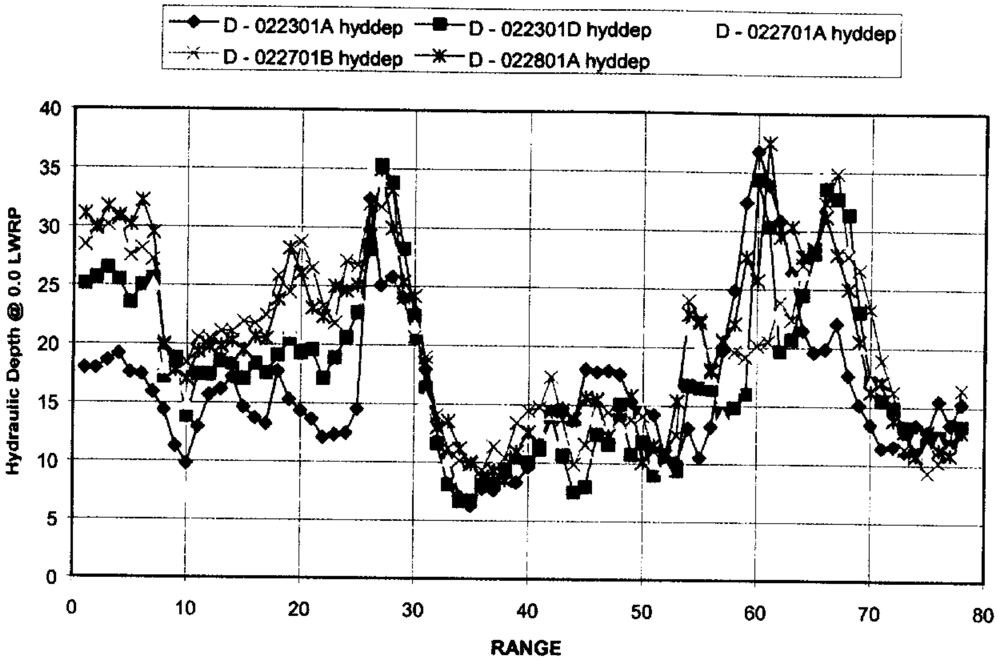

Figure A-46 Repeatability of Hydraulic Depth in Model Reach, Kate-Aubrey 1:16,000 Model

The repeatability for the five Kate-Aubrey 1:16,000 micromodel surveys was expressed by statistical variance for seven ranges. Variance was calculated at equal intervals of 100 feet across each range. Therefore, bed elevations were interpolated at each position for the analysis. Figures A-39 to A-45 show the model cross-section elevations. Computed values of variance for the seven Kate-Aubrey ranges follow.

Range 10 Average Variance:	20.7 feet^2
Range 20 Average Variance:	14.0 feet^2
Range 30 Average Variance:	37.0 feet^2
Range 40 Average Variance:	16.7 feet^2
Range 50 Average Variance:	9.6 feet^2
Range 60 Average Variance:	30.6 feet^2
Range 70 Average Variance:	11.8 feet^2
Overall Average Variance:	20.0 feet^2

Because variance is a function of the spread in elevations being analyzed, minimum to maximum within the cross-section, variance values cannot be used in comparing cross-sections or reaches having dissimilar characteristics. Variance, therefore, only provides a relative comparison between individual locations.

APPENDIX B

PREVIOUS LARGE-SCALE LOOSE-BED MODEL STUDIES

Appendix B: Previous Large-Scale Model Investigations

Name (River)	Prototype Data Used in Model Verification	Horizontal Scale[a]	Distortion (Horiz:Vert.
Baleshed-Ajax Bar (Mississippi)	1967, 1968	600:1	10:1
Blountstown (Apalachicola)	1977, 1978	120:1	1.5:1
Buck Island (Mississippi)	1976, 1977, 1978, 1979	300:1	3:1
Chipola Cutoff (Apalachicola)	1978, 1979	120:1	1.5:1
Devil's Island (Mississippi)	1973	400:1	4:1
Dogtooth Bend, (Mississippi)	1977, 1983	400:1	4:1
Kate Aubrey (Mississippi)	1975, 1976	300:1	3:1
Lake Dardanelle (Arkansas)	1971, 1973	120:1	1.5:1
Lock & Dam #2 (Red River)	1978, 1981	120:1	1.5:1
Lock and Dam #4 (Red River)	1978, 1981	120:1	1.5:1
Loosahatachie-Memphis (MS)	Jan 1986, Nov 1986	300:1	3:1
New Madrid Bar (Mississippi)	1976, 1977	480:1	8:1
Redeye Crossing (Mississippi)	1982, 1983	240:1	1.2:1
Smithland Locks & Dam (Ohio)	1983	150:1	1:1
West Access (Atchafalaya)	1989	120:1	1.5:1
Willamette River	1977, 1980	100:1	2:1
[a]Scale is prototype/model ratio.			

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

Waterways Experiment Station Individual Study Results

1.1. Baleshed-Ajax Bar Reach, Mississippi River

Location: Baleshed-Ajax Bar reach is located about 485 river miles about Head of Passes (AHP) on the Mississippi River.

Purpose of Study: The purpose of the Baleshed-Ajax Bar reach study was to determine the effectiveness of a proposed dike system and the effectiveness of alternate systems using vane dikes and combination of vane and spur dikes of troublesome reaches on the Mississippi River.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey April 1967 (2) Prototype survey October 1968 and, (3) Verification Test survey.

Scale: The movable-bed model used for this study reproduced to a horizontal scale of 1:600 and a vertical scale of 1:60 reproducing approximately 18 miles of the Mississippi River between river miles 478.6 and 496.4

Thalweg Index: Thalweg index was calculated using an Index width of 2500 feet. The index width defined the active channel width for this reach.

Type of Model: Sand bed.

Reference: J. J. Franco, J. E. Glover, and T. J. Pokrefke. (1970). "Investigation of Proposed Dike Systems on the Mississippi River, Report 1, Baleshed-Ajax Bar Reach, Hydraulic Model Investigation," Miscellaneous Paper H-70-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.2. Blountstown Reach, Apalachicola River

Location: The location of Blountstown Reach is between navigation miles 81 and 76 on the Apalachicola River.

Purpose of Study: The model study was considered essential to determine the effects of proposed methods of dredged material disposal and develop a contraction works plan to improve the navigation channel.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey June 1977, (2) Prototype survey June 1978, (3) Base Test survey, and (4) Verification Test survey.

Scale: The Blountstown Reach model was of the movable-bed type built to a horizontal scale of 1:120 and a vertical scale of 1:80.

Thalweg Index: Thalweg index was calculated using an Index width of 300 feet. The index width defined the active channel width for this reach.

Type of Model: The overbank and bed were molded in crushed coal having a median grain diameter of 4 mm and a specific gravity of 1.3. The fixed bank line and nonerodible bed material were molded in crushed stone. Stone-filled dikes were reproduced with crushed stone, and pile dikes were simulated by rows of metal rods.

Reference: R. A. McCollum. (1988). "Blountstown Reach, Apalachicola River, Movable-Bed Model Study," Technical Report HL-88-17, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.3. Buck Island Reach, Mississippi River

Location: The Buck Island reach of the Mississippi River is a straight reach of river where dike fields have been constructed to form a sinuous navigation channel. The reach is located approximately halfway between Memphis, Tennessee, and Helena, Arkansas at about 700 river miles AHP.

Purpose of Study: The purpose of the study was to obtain some indication of the effectiveness of the proposed dike systems to maintain the existing alignment and the feasibility of channel realignment, and to development any modifications that might be required.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey June 1976, (2) Prototype survey May 1977, (3) Prototype survey May 1978, (4) Prototype survey February 1979, (5) Base Test survey, and (6) Verification Test survey.

Scale: The movable-bed model reproducing approximately 12.5 miles of the Mississippi River between miles 690.5 and 703.0 AHP was used for this study reproduced to a horizontal scale of 1: 300 and a vertical scale of 1:100.

Thalweg Index: Thalweg index was calculated using an Index width of 2500 feet. The index width defined the active channel width for this reach.

Type of Model: Crushed coal of specific gravity of 1.30 and a medial grain size of about 4 mm was used for the bed material.

Reference: Charles R. Nickles, Thomas J. Pokrefke, Jr., and J. Edwin Glover. (1985). "Buck Island Reach, Mississippi River, Hydraulic Model Investigation," Technical Report HL-85-2, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.4. Chipola Cutoff Reach, Apalachicola River

Location: The model reproduced the reach of the Apalachicola River from navigation mile 42.7 to 39.5 and approximately one mile of the Chipola Cutoff.

Purpose of Study: This reach is one of which there is difficulty in maintaining an authorized navigation depth of 9-ft. The purpose of the study was due to the continuing decline in suitable sites for disposal of dredge material, various alternative methods of dealing with dredge material and construction of channel contraction works.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey January 1978, (2) Prototype survey June 1979, (3) Base Test survey, and (4) Verification Test survey.

Scale: The model was constructed to scales of 1:120 horizontally and 1:80 vertically.

Thalweg Index: Thalweg index was calculated using an Index width of 300 feet. The index width defined the active channel width for this reach.

Type of Model: The overbank and bed were molded in crushed coal having a median grain diameter of 4 mm and a specific gravity of 1.3. Fixed-bank line and bed rock were molded in crushed stone.

Reference: Randy A. McCollum, (1994), "Chipola Cutoff Reach, Apalachicola River, Movable-Bed Model Study," Technical Report HL-94-8, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.5. Devil's Island Reach, Mississippi River

Location: Devil's Island Reach of the Mississippi River is located about 5 miles upstream of Cape Girardeau, Missouri between miles 55.0 and 68.0 above the mouth of the Ohio River.

Purpose of Study: The purpose of the study was to evaluate the effectiveness of a proposed plan of improvement and to develop modifications considered necessary to provide a satisfactory channel for navigation.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey November 1969, and (2) Verification Test survey.

Scale: A movable-bed model with scale rations of 1:400 horizontal and 1:100 vertical, reproducing approximately 13.0 miles of the Mississippi River was used in this study.

Thalweg Index: Thalweg index was calculated using an Index width of 1500 feet. The index width defined the active channel width for this reach.

Type of Model: The movable-bed model bed material was coal which a medial grain size of about 4 mm and a specific gravity of 1.30.

Reference: J. J. Franco and C. D. McKellar, Jr. (1973). "Channel Conditions, Devil's Island Reach, Mississippi River, Missouri and Illinois," Technical Report H-73-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.6. Dogtooth Bend Reach, Mississippi River

Location: The Dogtooth Beach reach of the middle Mississippi River extends from mile 39.6, Thebes Gap to mile 20.2, Thompson Landing (river miles above mile zero, which is located at the confluence of the Ohio and Mississippi Rivers near Cairo, IL).

Purpose of Study: This hydraulic model study was undertaken to obtain some indication of the effectiveness of the various proposed river training structure plans.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey March 1977, (2) Prototype survey April 1983, (3) Base Test survey, and (4) Verification Test survey.

Scale: The movable-bed model used for this study reproduced to a horizontal scale of 1:400 and a vertical scale of 1:100.
Thalweg Index: Thalweg index was calculated using an Index width of 1500 feet. The index width defined the active channel width for this reach.

Type of Model: The movable-bed model consisted of crushed, granulated coal with a specific gravity of 1.30 and median grain size of approximately 4 mm as the movable bed material.

Reference: David L. Derrick, Thomas J. Pokrefke, Jr., Marden B. Boyd, James P. Crutchfield, and Raymond R. Henderson. (1994). "Design and Development of Bendway Weirs for the Dogtooth Bend Reach, Mississippi River, Hydraulic Model Investigation," Technical Report HL-94-10, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.7. Kate Aubrey Reach, Mississippi River

Location: Kate Aubrey Reach is located approximately 60 miles north of Memphis, TN between river miles 785.5 and 797.0.

Purpose of Study: The purpose of this study was to determine the extent of the shoaling in between Keyes Point dikes and Kate Aubrey dikes (river miles 788.5 and 792.5).

Problem Area: The problem area was in between Keyes Point dikes and Kate Aubrey dikes (river miles 788.5 and 792.5).

Data: Data used in this study was as follows: (1) Prototype survey May 1975, (2) Prototype survey May 1976, (3) Base Test survey, and (4) Verification Test survey.

Scale: The vertical scale was 1:100 and the horizontal scale was 1:300.

Thalweg Index: Thalweg index was calculated using an Index width of 2500 feet. The index width defined the active channel width for this reach.

Type of Model: The model used for this study was a movable-bed model with crushed coal of median diameter 4 mm and a specific gravity of 1.30.

Reference: Charles R. Nickles. (2000). Unpublished report, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.8. Lake Dardanelle, Arkansas River

Location: Lake Dardanelle is a 51-mile-long reservoir formed by Dardanelle Lock and Dam, one of the four high-lift structures in the system. Dardanelle Dam is located on the Arkansas River at mile 205.5, 2 miles upstream from Dardanelle and 3 miles southwest of Russellville.

Purpose of Study: The purpose of the study was to determine the type and location of control structures needed to develop a stable navigation channel with a satisfactory alignment in the vicinity of the proposed bridge by the Arkansas Highway Department and to make Lake Dardanelle an efficient sediment trap.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey November 1971, (2) Prototype survey October 1973, (3) Base Test survey, and (4) Verification Test survey.

Scale: The model of Lake Dardanelle, which reproduced the reach of the Arkansas River from mile 231.3 to 238.5 was built to linear scale ratios of 1:120 horizontally and 1:80 vertically.

Thalweg Index: Thalweg index was calculated using an Index width of 1500 feet. The index width defined the active channel width for this reach.
Type of Model: The model was of the movable-bed type with fixed-banks and overbanks molded in sand-cement mortar. The bed material was coal having a median grain diameter of about 4 mm and a specific gravity of 1.30.

Reference: James E. Foster and John J. Franco. (1977) "Lake Dardanelle, Arkansas River, Hydraulic Model Investigation," Technical Report H-77-4, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.9. Lock and Dam #2, Red River

Location: The John H. Overton Lock and Dam is located in a cutoff channel between 1967 river miles 89.0 and 86.5 on the Red River.

Purpose of Study: The purposes of the model study were (1) to study tendency for scour fill in the approaches to the lock and dam, and (2) determine training structures that would improve navigation conditions and minimize dredging requirements and scour problems.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey 1978, (2) Prototype survey 1981, (3) Base Test survey, and (4) Verification Test survey.

Scale: A model reproducing a reach of the Red River from 1967 river miles 90.0 to 85.0 was designed for movable-bed operations and built to linear scale rations of 1:120 horizontally and 1:80 vertically.

Thalweg Index: Thalweg index was calculated using an Index width of 400 feet. The index width defined the active channel width for this reach.

Type of Model: A movable-bed model was used with crushed coal that had a median diameter of 4 mm and a specific gravity of 1.30.

Reference: Randy A. McCollum. (1997) "Red River Waterway, John H. Overton Lock and Dam, Report 3, Sedimentation Conditions, Hydraulic Model Investigation" Technical Report HL-98-16, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.10. Lock and Dam #4, Red River

Location: Lock and Dam No. 4 is the fourth lock and dam on the Mississippi River to Shreveport reach of the Red River waterway. The proposed lock and dam will be located in a cutoff between 1967 river miles 205 and 210.

Purpose of Study: The purpose of the study was to investigate and solve potential channel development and maintenance problems associated with Lock and Dam No.4 on the Red River in Louisiana.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey 1978, (2) Prototype survey 1981, (3) Base Test survey, and (4) Verification Test survey.

Scale: The model reproduced the Red River 1967 river mile 213.1 to 204.7 using a distorted scale of 1:120 horizontally and 1:80 vertically.

Thalweg Index: Thalweg index was calculated using an Index width of 550 feet. The index width defined the active channel width for this reach.

Type of Model: The bed of the model was molded in crushed coal having the following properties: d_{84} = 5.5 mm, d_{50} = 2.9 mm, d_{16} = 1.5 mm, and a specific gravity of 1.30.

Reference: D. S. Mueller, D. M. Maggio, and T. J. Pokrefke. (1992) "Red River Waterway, Lock and Dam No. 4, Report 3, Sedimentation Conditions, Hydraulic Model Study," Technical Report HL-90-2, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.11. Loosahatchie-Memphis Reach, Mississippi River

Location: The Loosahatchie-Memphis reach is the portion of the lower Mississippi River that lies adjacent to Memphis, TN. The reach includes the entrance to the Memphis Harbor, the confluence with the Wolf and Loosahatchie Rivers and Mud Island and is crossed by four bridges.

Purpose of Study: The purpose of the study was (1) to investigate the increasing shoaling upstream of the I-40 Highway bridge and the increased dredging requirements to maintain a channel through the I-40 bridge during low-water periods, and (2) to investigate the instability of the left riverbank immediately downstream of the entrance to the harbor.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey January 1986, (2) Prototype survey November 1986, (3) Prototype survey April 1990, (4) Base Test survey, and (5) Verification Test survey.

Scale: The movable-bed model use for this study reproduced to a horizontal scale of 1:300 and a vertical scale of 1:100 the reach of the Mississippi River between miles 738.8 and 743.5 AHP including the overbank area between the main-line levees.

Thalweg Index: Thalweg index was calculated using an Index width of 2500 feet. The index width defined the active channel width for this reach.

Type of Model: The model was a movable-bed type and was constructed with the banks fixed about el +10 and the overbank areas molded in sand-cement mortar. The steep portions of the banks below el +10 and all dikes were molded using 19-mm (3/4-in.) crushed stone. The remaining river channel was molded in crushed coal having a median diameter of 2 mm and a specific gravity of 1.30.

Reference: Charles R. Nickles. (1996). "Loosahatchie-Memphis Reach, Lower Mississippi River, Hydraulic Model Investigation," Technical Report HL-96-4, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.12. New Madrid Bar Reach, Mississippi River

Location: The location of this study is a reach of the Mississippi River between miles 882.5 and 893.5 AHP, in the vicinity of New Madrid, MO.

Purpose of Study: The model study was undertaken to obtain some general indications as to the effectiveness of the proposed plan of a system of dikes designed to improve the alignment of the navigation channel and eliminate the need for maintenance dredging.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey May 1976, (2) Prototype survey May 1977, (3) Prototype survey April 1978, (4) Base Test survey, and (5) Verification Test survey.

Scale: The movable-bed model used for this study reproduced to a horizontal scale of 1:480 and a vertical scale of 1:60 the reach of the Mississippi River between miles 882.5 and 893.5 AHP.

Thalweg Index: Thalweg index was calculated using an Index width of 2500 feet. The index width defined the active channel width for this reach.

Type of Model: The bed material used was sand having a median grain diameter of about 0.2 mm and specific gravity of 2.65.

Reference: Thomas J. Pokrefke, Jr., and John J. Franco. (1981) "Investigation of Proposed Dike System on the Mississippi River, Report 2, New Madrid Bar Reach, Hydraulic Model Investigation," Miscellaneous Paper H-70-1, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.13. Redeye Crossing Reach, Lower Mississippi River

Location: Redeye Crossing is located on the lower Mississippi River between river miles 223 and 225, Above Head of Passes (AHP), about 3 miles downstream of the I-10 Highway Bridge at Baton Rouge, LA.

Purpose of Study: The purpose of the Redeye Crossing Reach study was to evaluate the effectiveness of proposed constricting dikes at Redeye Crossing in reducing maintenance dredging requirements while maintaining safe navigation conditions through the reach.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey September 1982 (2) Prototype survey August 1983 (3) Verification Test survey, and (4) Base Test survey.

Scale: The movable-bed model used for this study reproduced to a horizontal scale of 1:240 and a vertical scale of 1:200 the reach of the Mississippi River between miles 219.0 to 228.0 AHP.

Thalweg Index: Thalweg index was calculated using an Index width of 2500 feet. The index width defined the active channel width for this reach.

Type of Model: This model used crushed coal having a medial diameter of 2 mm and a specific gravity of 1.30.

Reference: T. J. Pokrefke, Jr., C. R. Nickles, N. K. Raphelt, M. J. Trawle, and M. B. Boyd. (1995). "Redeye Crossing Reach, Lower Mississippi River, Report 1, Sediment Investigation," Technical Report HL-95-13, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.14. Smithland Locks and Dam, Ohio River

Location: Smithland Locks and Dam is located on the Ohio River at mile 918.5 below Pittsburgh, Pennsylvania. The site is about 2 miles upstream from Smithland, Kentucky, and about 16 miles upstream from Paducah, Kentucky.

Purpose of Study: The purpose of the model investigation was to determine the following:

a. Optimum location and location and alignment of the locks and arrangement of the lock auxiliary walls.
b. Navigation conditions in the lock approaches and over the fixed weir with the various plans considered.
c. Shoaling and erosion tendencies.
d. Effects of various amounts of rock excavations.
e. Optimum alignment for the lock lower approach channel and training structures required to eliminate or reduce the need for maintenance dredging.
f. Effects of various dam modifications.
g. Conditions that can be expected during construction with various phase cofferdams.
h. Modification required to eliminate any undesirable conditions or to improve the efficiency of the project.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey October 1965, and (2) Verification Test survey.

Scale: The model was constructed to an undistorted scale ratio of 1:150.

Thalweg Index: Thalweg index was calculated using an Index width of 1000 feet. The index width defined the active channel width for this reach.

Type of Model: The model was constructed initially as a fixed-bed type with provisions for converting a portion of the cannel bed upstream and downstream of the proposed damsite to a movable bed. Except for the reach between miles 917.5 and 925.0, the channel bed and overbank area were molded in sand-cement mortar to sheet metal templates. The section of the model to be converted to movable bed was molded initially with pea gravel that was later replaced with crushed coal. The reach of the model between miles 917.5 and 925.0, without the locks and dam, was converted to a movable bed reproduced with crushed coal and molded to the conditions indicated by the prototype survey of October 1966.

Reference: John J. Franco and Thomas J. Pokrefke, Jr. (1983). "Smithland Locks and Dam, Ohio River, Hydraulic Model Investigation," Technical Report HL-83-19. U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.15. West Access Channel, Atchafalaya River

Location: The location of this study is a reach of the Atchafalaya River between miles 72.9 and 77.4, including the entrance and approximately 2.9 miles of the upstream end of the West Access Channel. This entrance is located at Atchafalaya River mile 76.8, which is approximately 37 river miles downstream of Krotz Springs, LA, and 40 miles upstream of Morgan City, LA.

Purpose of Study: The purpose of the study was to investigate the relocation of the entrance of the West Access Channel approximately 3 miles upstream of its present site and realign the upper portion of the channel. The model study was undertaken to obtain some indication of the effectiveness of the proposed relocation and realignment to reduce the sediment entering the channel and the effects on the Atchafalaya River Channel.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey 1975, and (2) Verification Test survey.

Scale: The movable-bed model used for this study reproduced to a horizontal scale of 1:120 and a vertical scale of 1:80 the reach of the Atchafalaya River between miles 72.9 and 77.4.

Thalweg Index: Thalweg index was calculated using an Index width of 1100 feet. The index width defined the active channel width for this reach.

Type of Model: The model was constructed with the banks fixed above el 0.0 and the overbank area molded in sand-cement mortar. The Atchafalaya River Channel below el 0.0 feet referred to the National Geodetic Vertical Datum (NGVD) from mile 72.9 to mile

75.8 was reproduced using ¾-in. crushed stone. This area was fixed after a study of geological survey and prior hydrographic surveys of the channel indicated that the river channel was entrenched in a layer of back-swamp clay, which is highly resistant to erosion. The remaining river channel from mile 75.8 to mile 77.4 and the West Access Channel were molded in crushed coal having a medial diameter of 2 mm and a specific gravity of 1.30.

Reference: D. M. Maggio and C. R. Nickles. (1989) "West Access Channel Realignment Atchafalaya River, Hydraulic Model Investigation," Technical Report HL-89-2, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

1.16. Bass Location, Willamette River

Location: The Bass Location, Willamette River, is located between river miles 137 and 135, just southeast of Corvallis, Oregon.

Purpose of Study: The model study was conducted to look at the alternative of using stone groins as a method of bank protection instead of blanket stone revetment.

Problem Area:

Data: Data used in this study was as follows: (1) Prototype survey 1977, (2) Prototype survey 1980, (3) Base Test survey 25-year flood, (4) Base Test survey 2-year flood, and (5) Verification Test survey.

Scale: The model was built to a horizontal scale of 1:100 and a vertical scale of 1:50.

Thalweg Index: Thalweg index was calculated using an Index width of 500 feet. The index width defined the active channel width for this reach.

Type of Model: Portions of the right overbank and all the left overbank were molded in concrete. The difference in the bed and bank material was simulated by using different grain size material in the channel and the erodible section of bank line. The right bank in the area of concern was molded in crushed coal having a medial grain diameter of 4 mm, and the bed of the model was molded in crushed coal having a median grain diameter of about 10 mm. The specific gravity of the coal was 1.30.

Reference: Randy A. McCollum, C. Wayne O'Neal, and J. Edwin Glover. (1987) "Bank Protection, Bass Location, Willamette River, Oregon," Technical Report HL-87-7, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 39180.

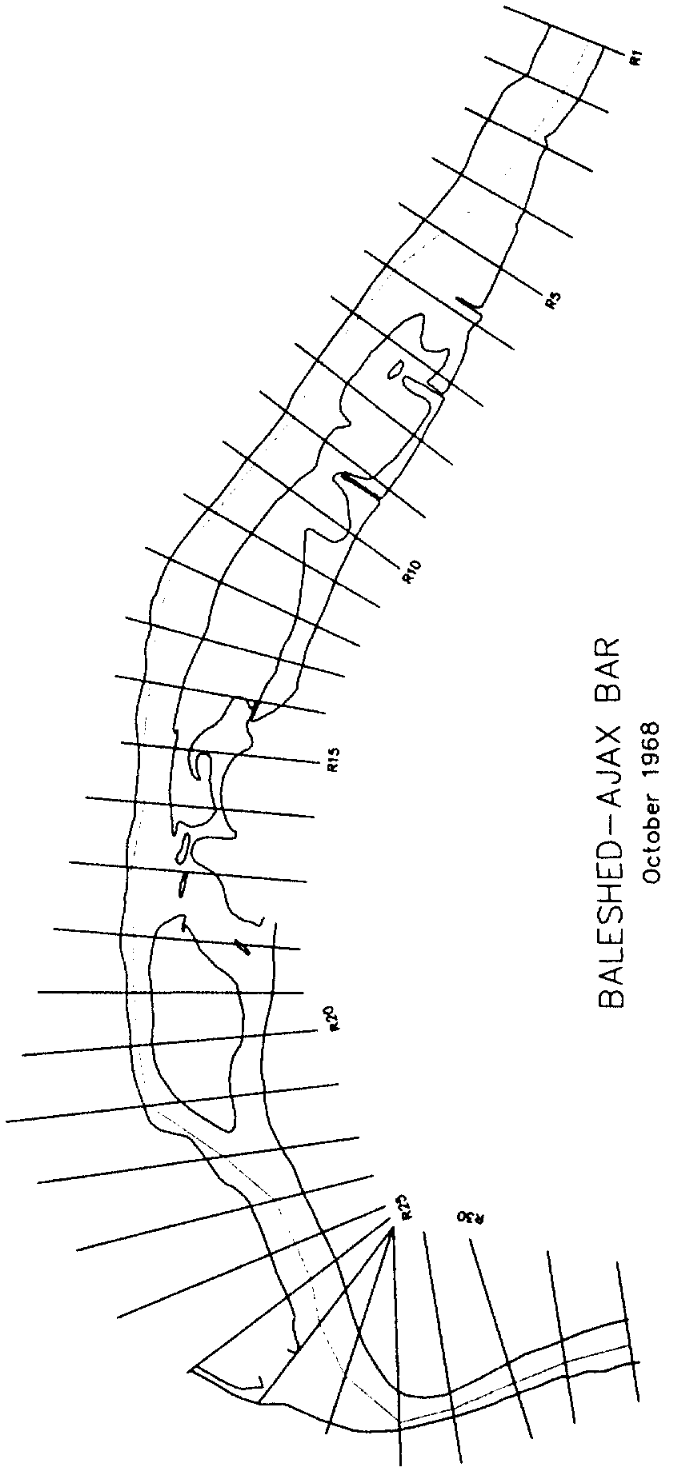

Figure B-1.1a Baleshed-Ajax Bar Model Plan View

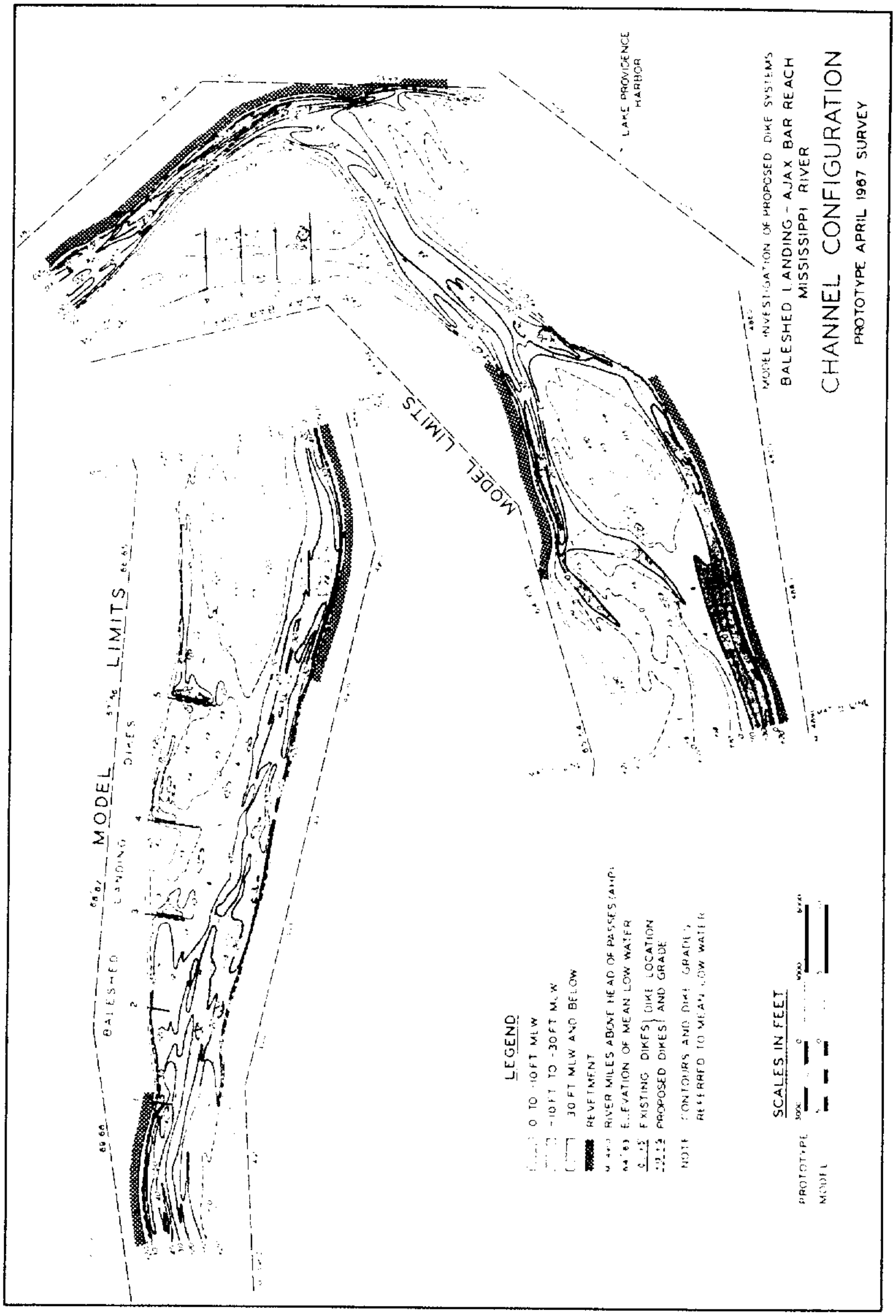

Figure B-1.1b Baleshed-Ajax Bar April 1967 Prototype Survey

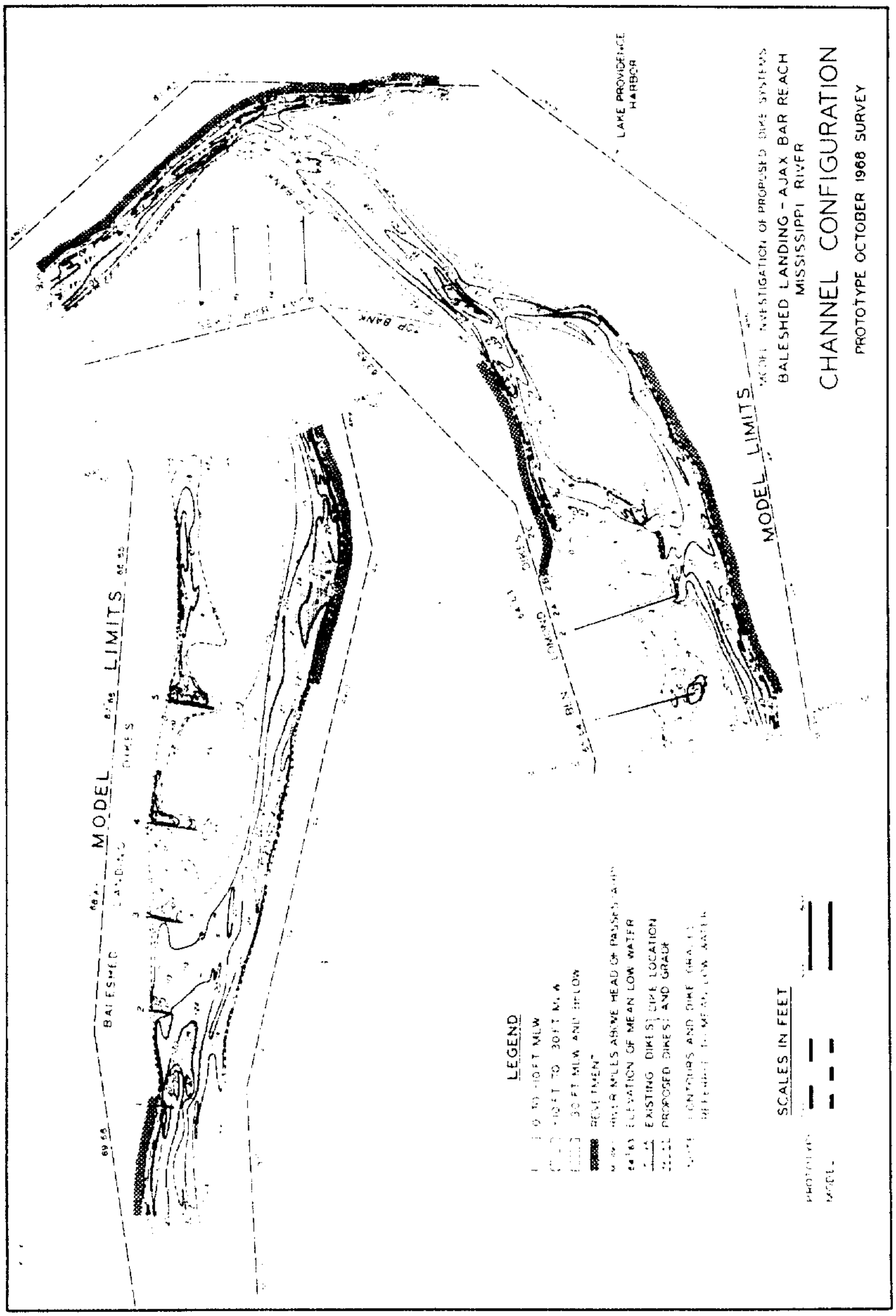

Figure B-1.1c Baleshed-Ajax Bar October 1968 Prototype Survey

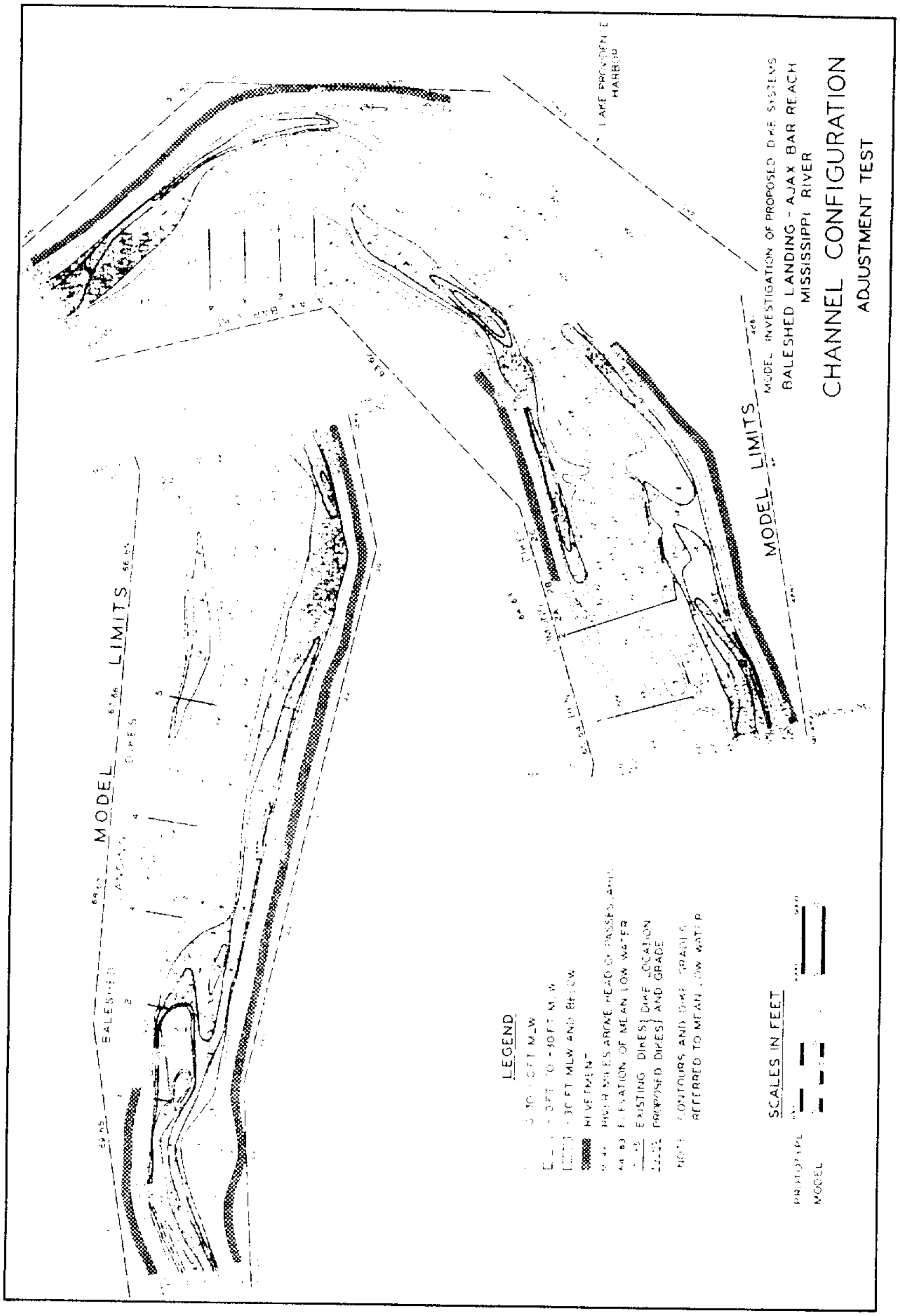

Figure B-1.1d Baleshed-Ajax Verification Test Survey

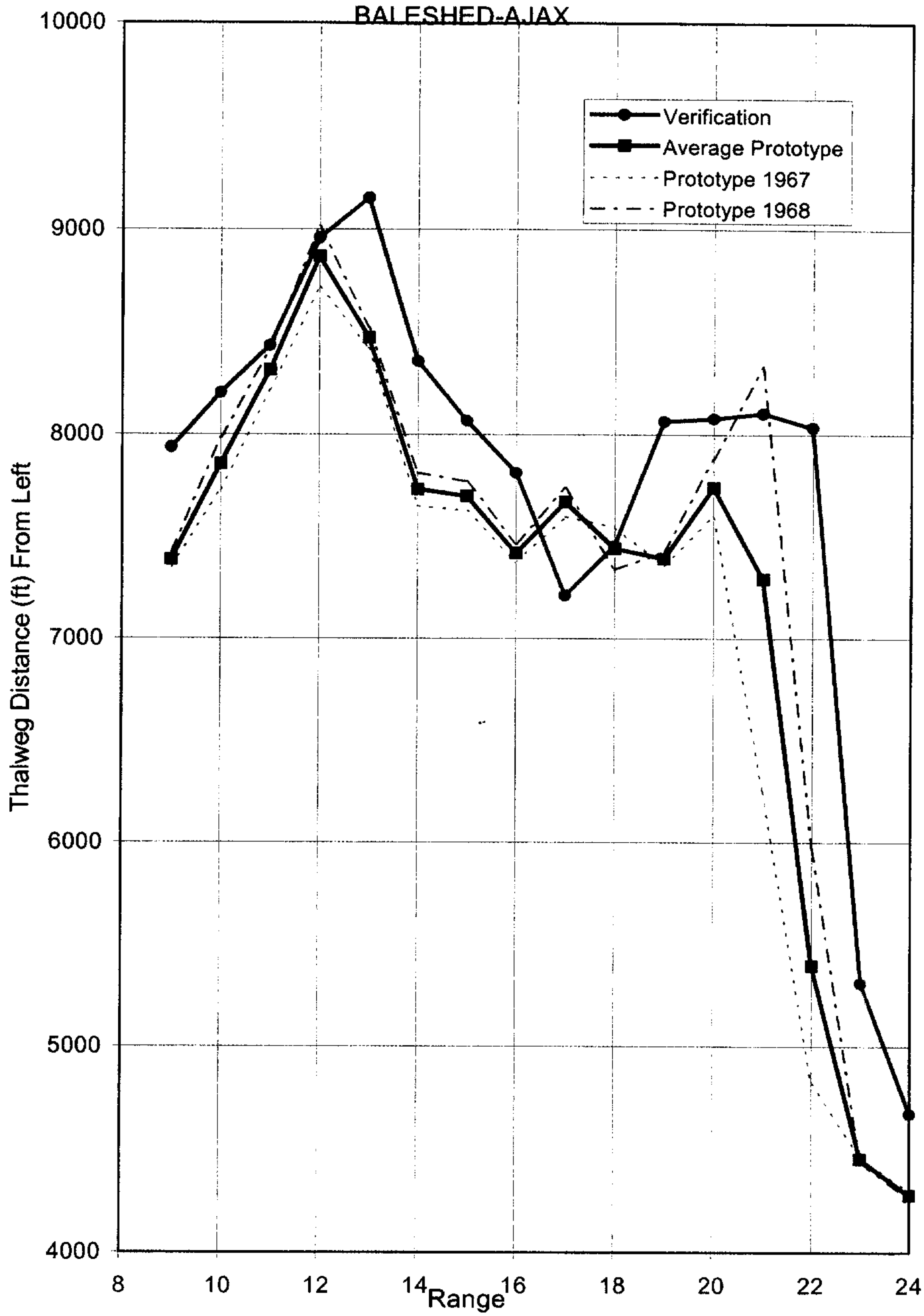

Figure B-1.2a Thalweg Position From Left, Baleshed-Ajax

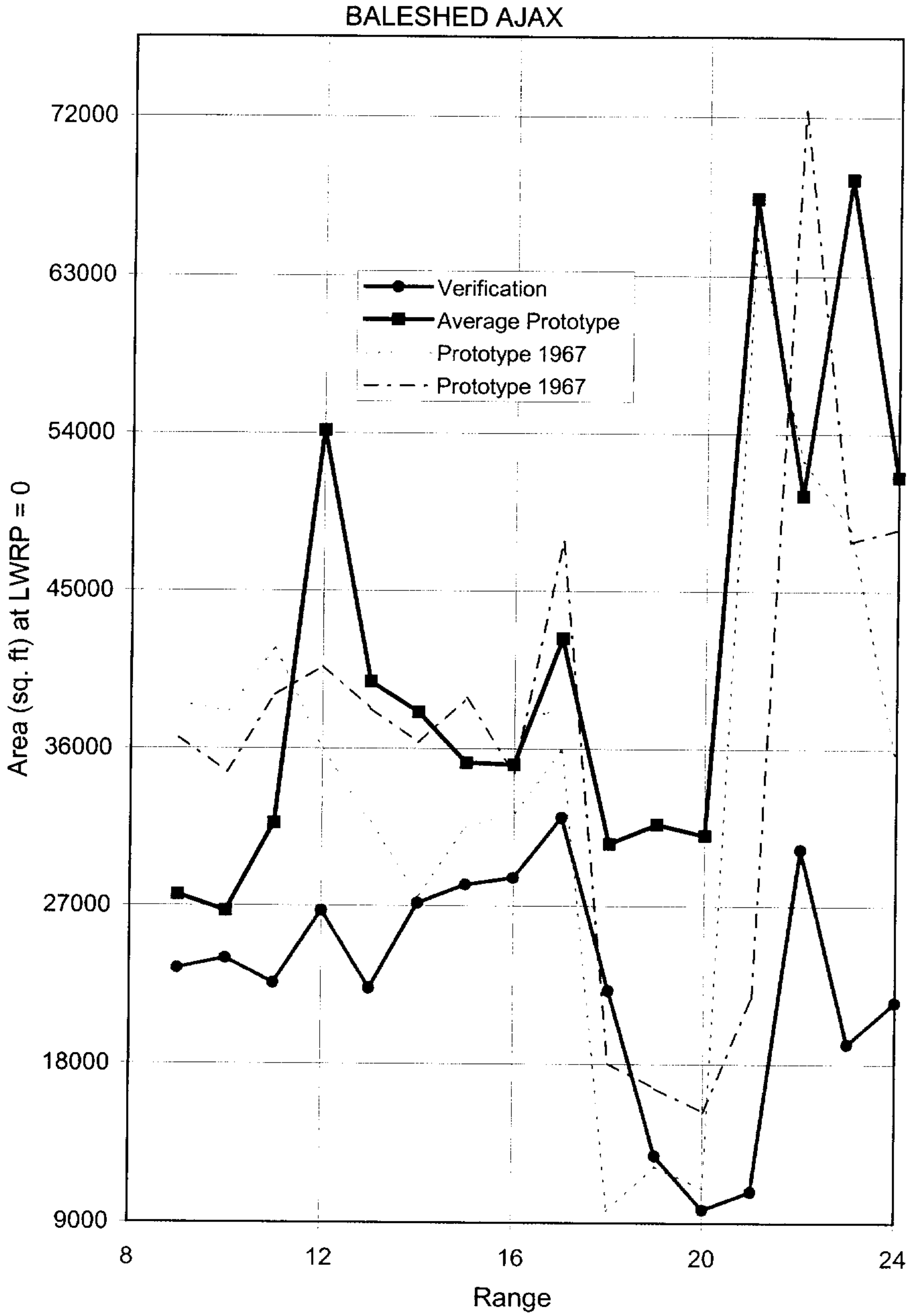

Figure B-1.2b Cross-Section Area by Range, Baleshed-Ajax

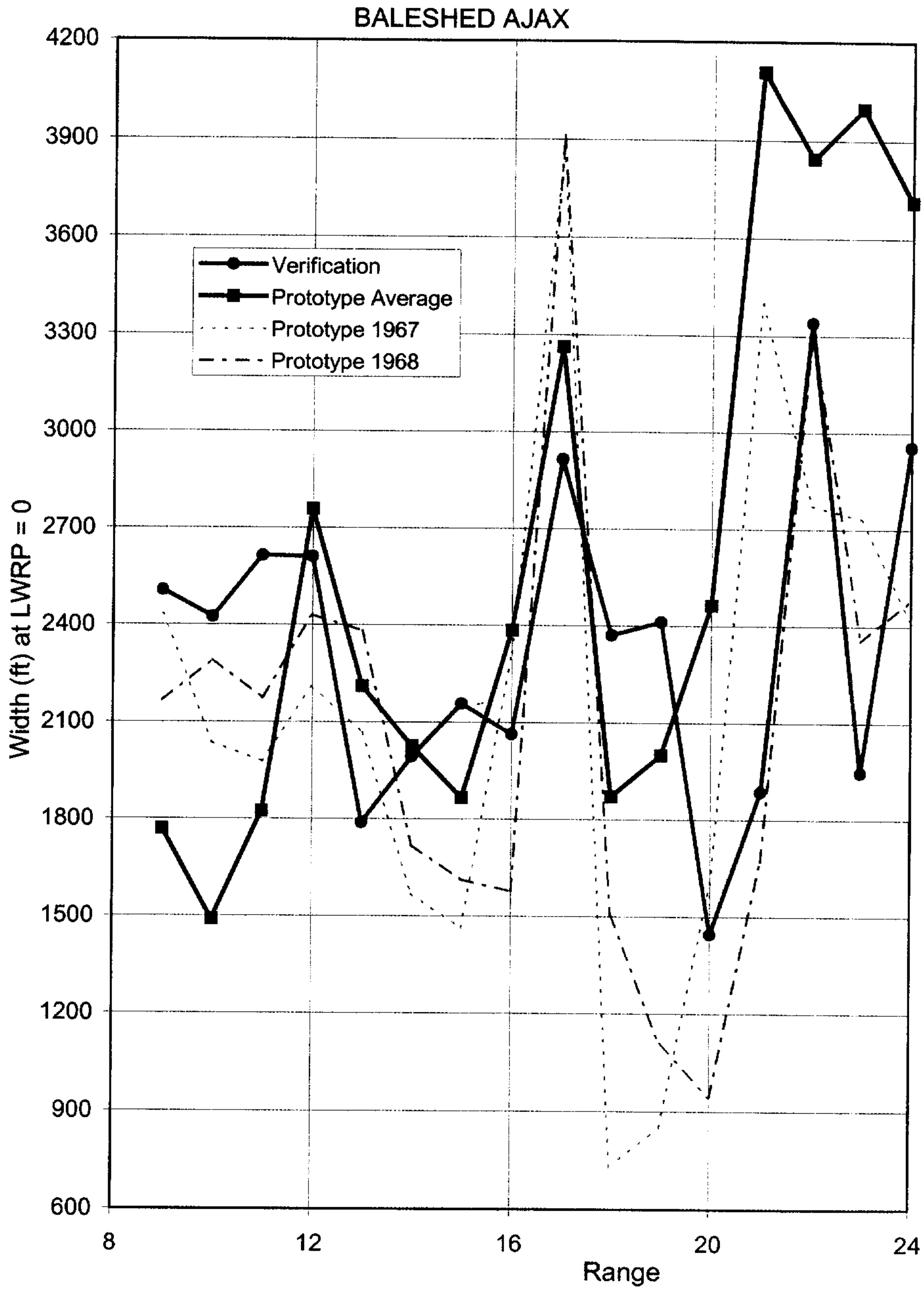

Figure B-1.2c Top Width by Range, Baleshed-Ajax

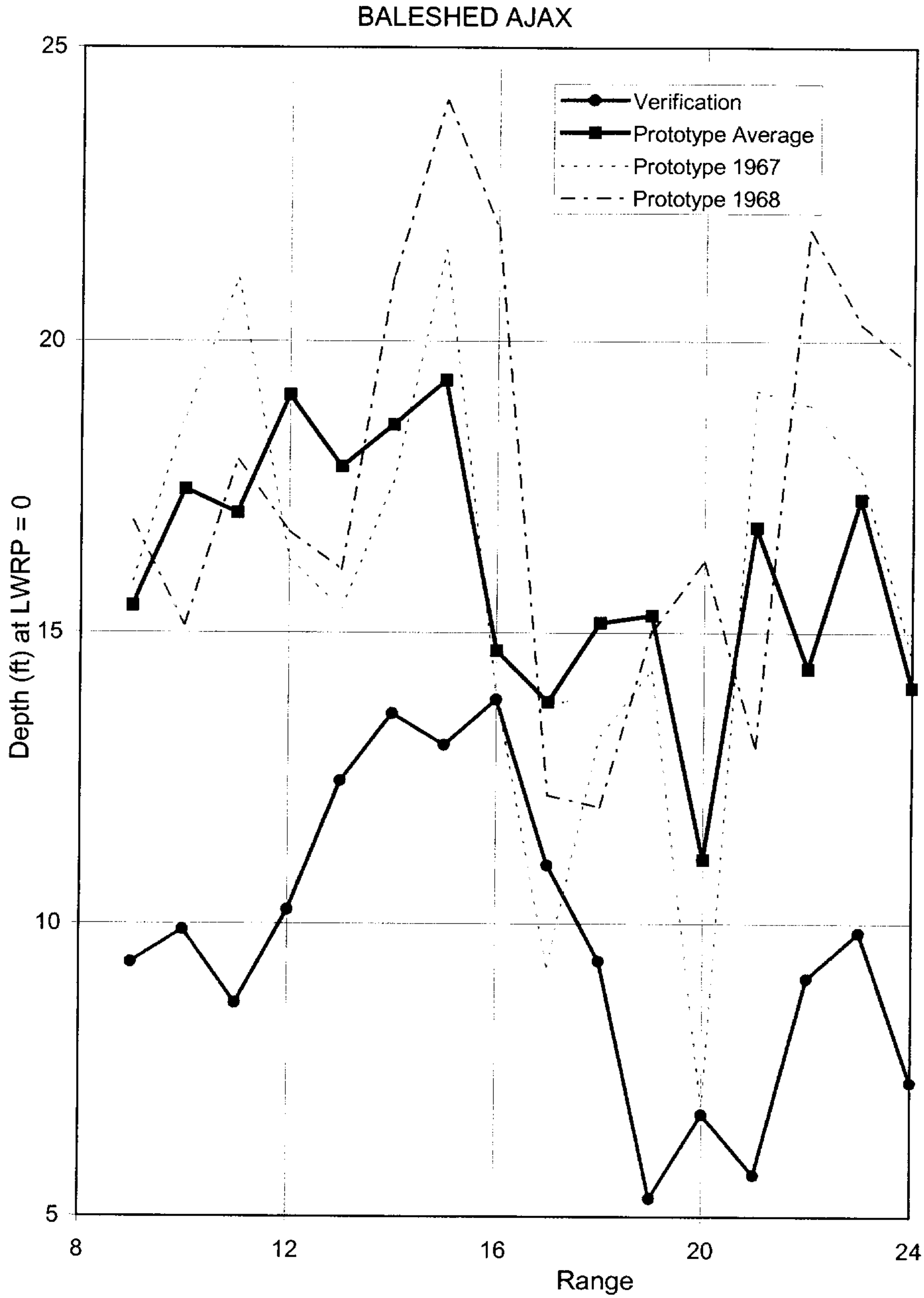

Figure B-1.2d Hydraulic Depth by Range, Baleshed Ajax

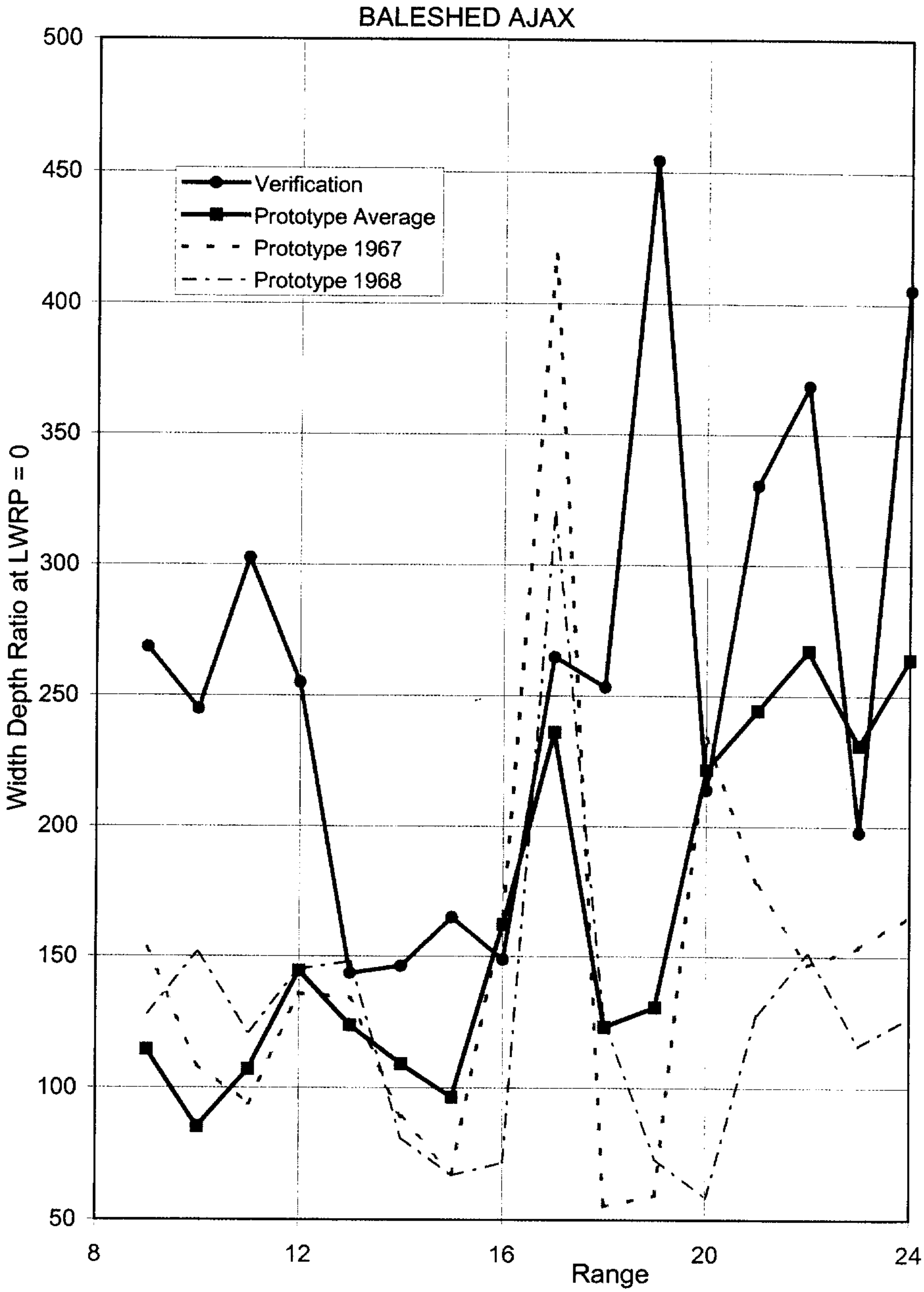

Figure B-1.2e Width/Depth Ratio by Range, Baleshed-Ajax

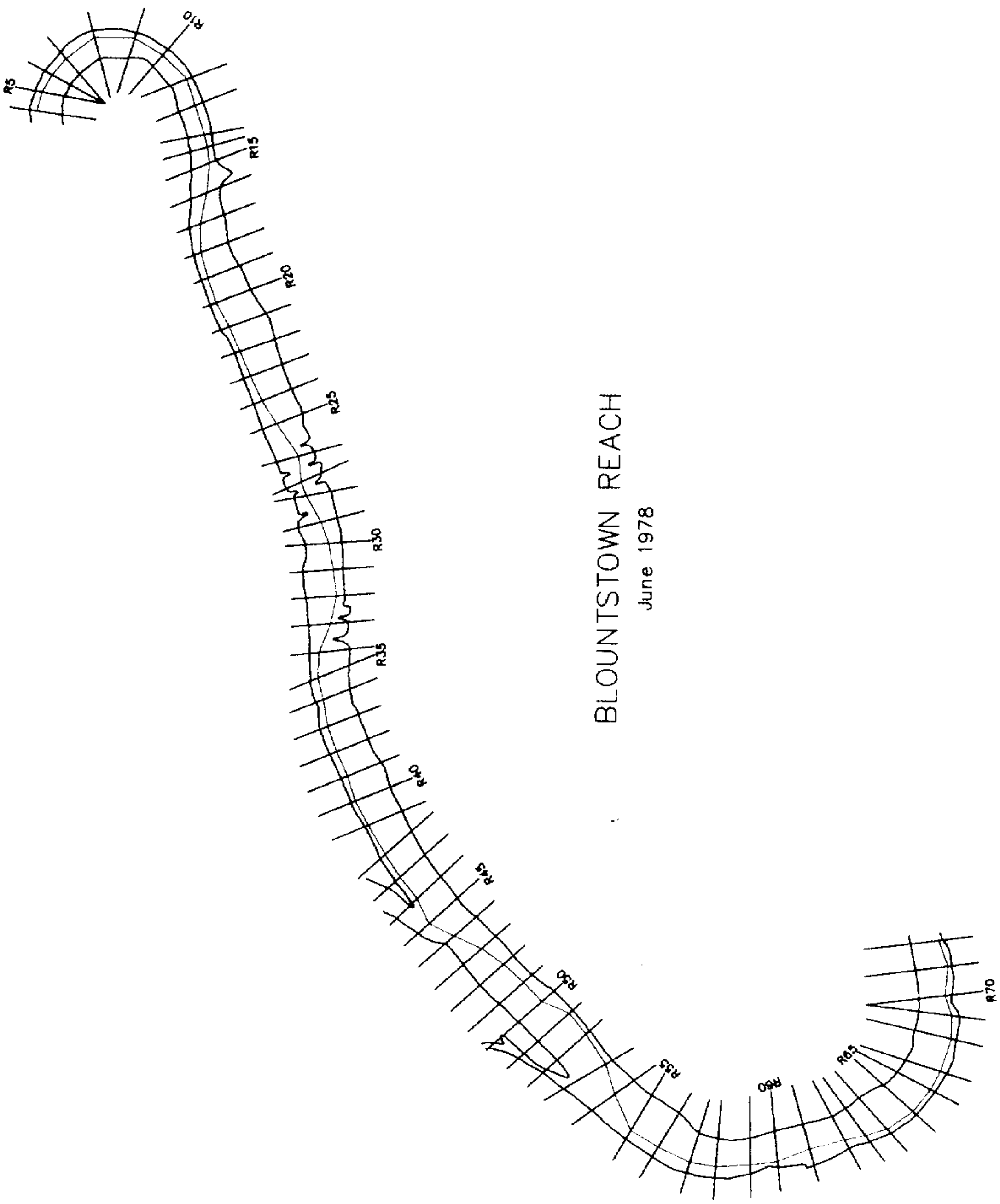

Figure B-2.1a Blountstown Model Plan View

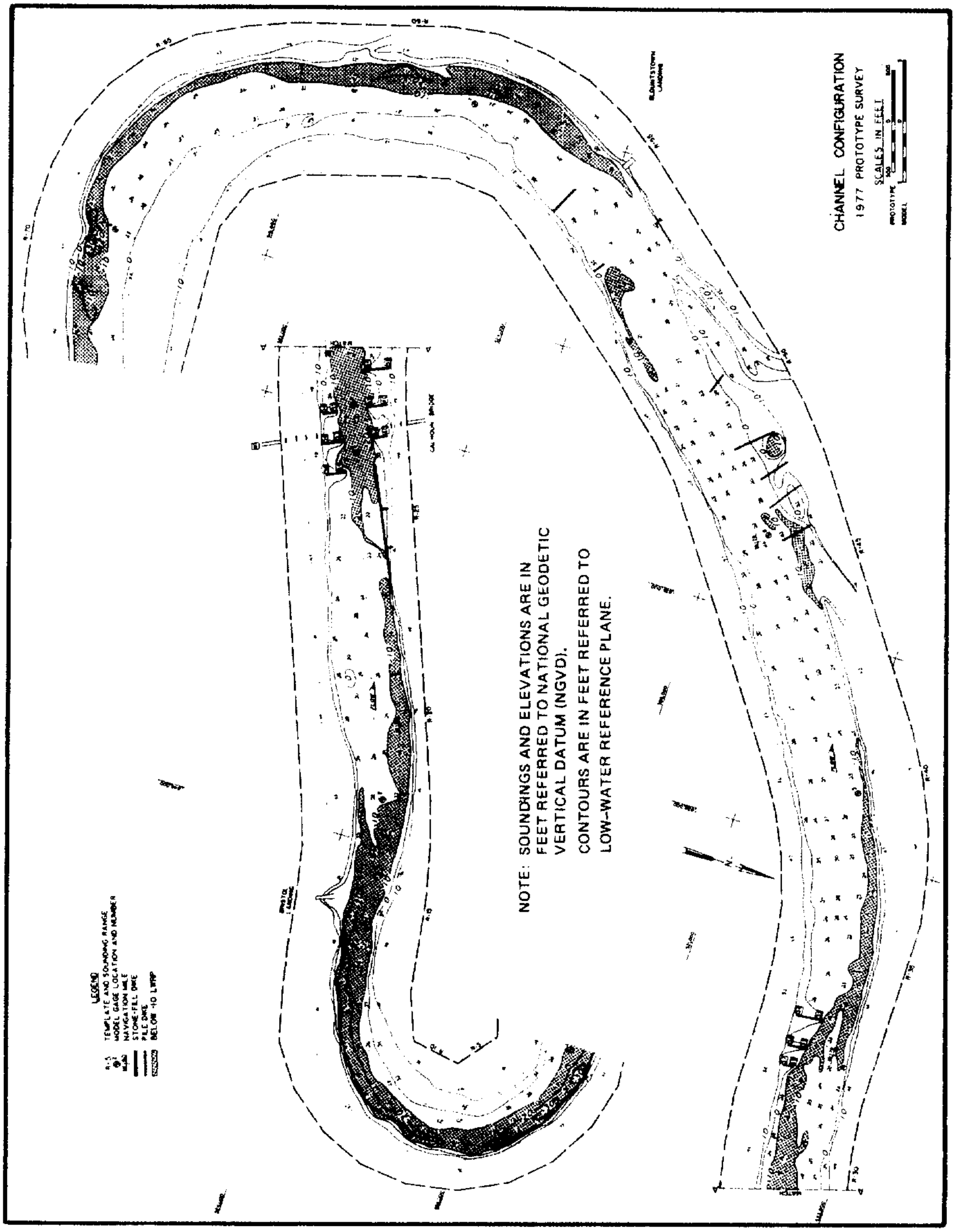

Figure B-2.1b Blountstown June 1977 Prototype Survey

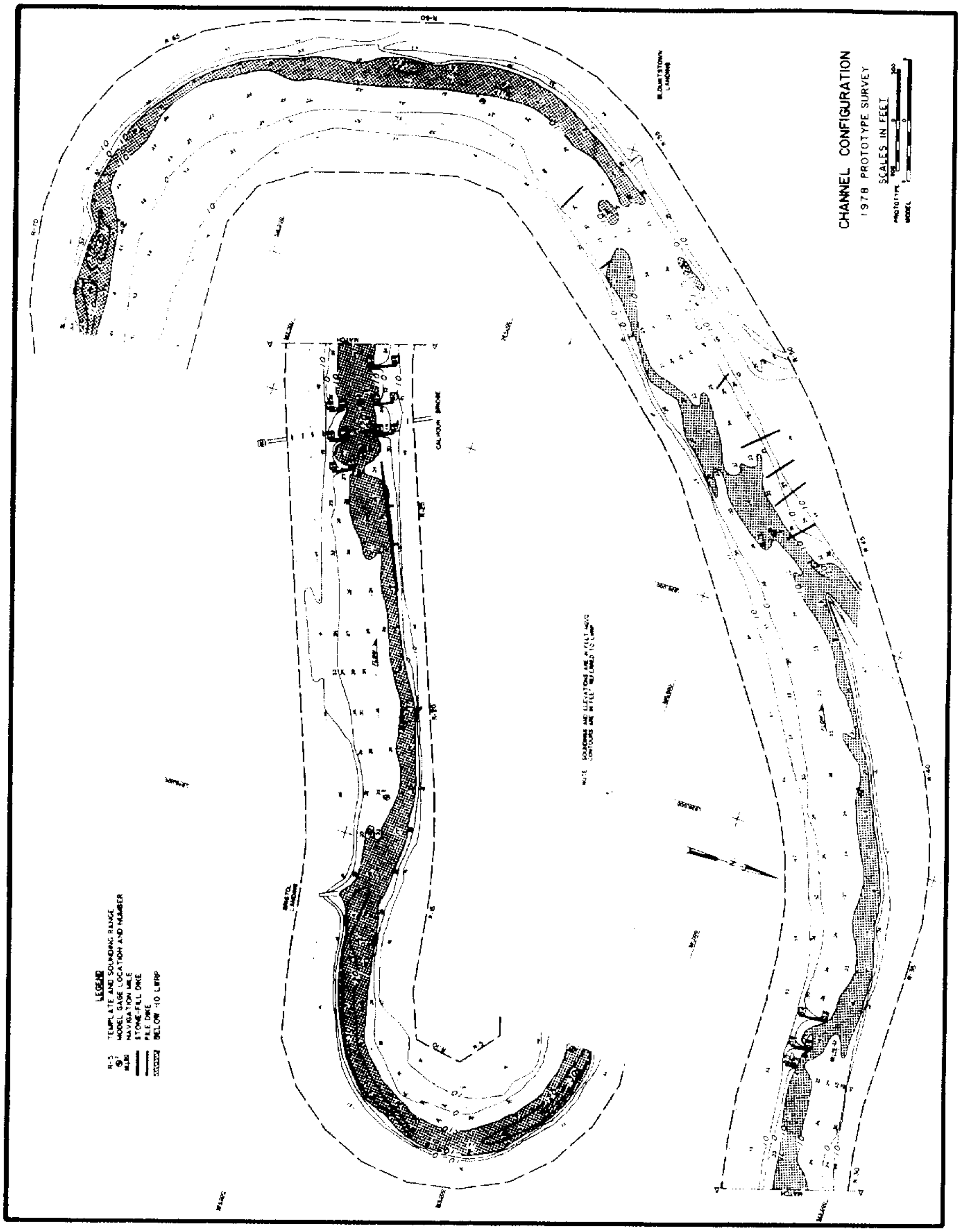

Figure B-2.1c Blountstown June 1978 Prototype Survey

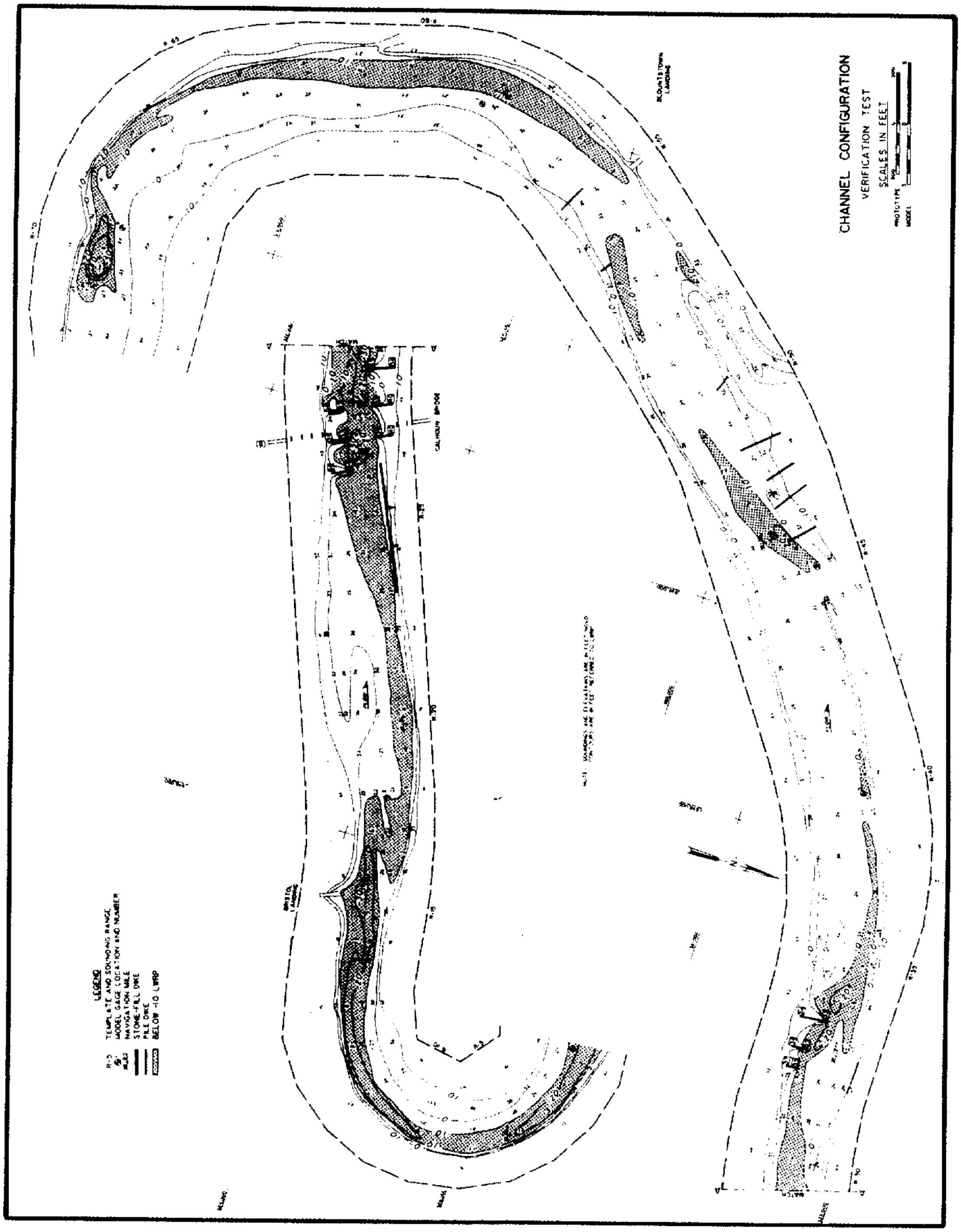

Figure B-2.1d Blountstown Verification Test Survey

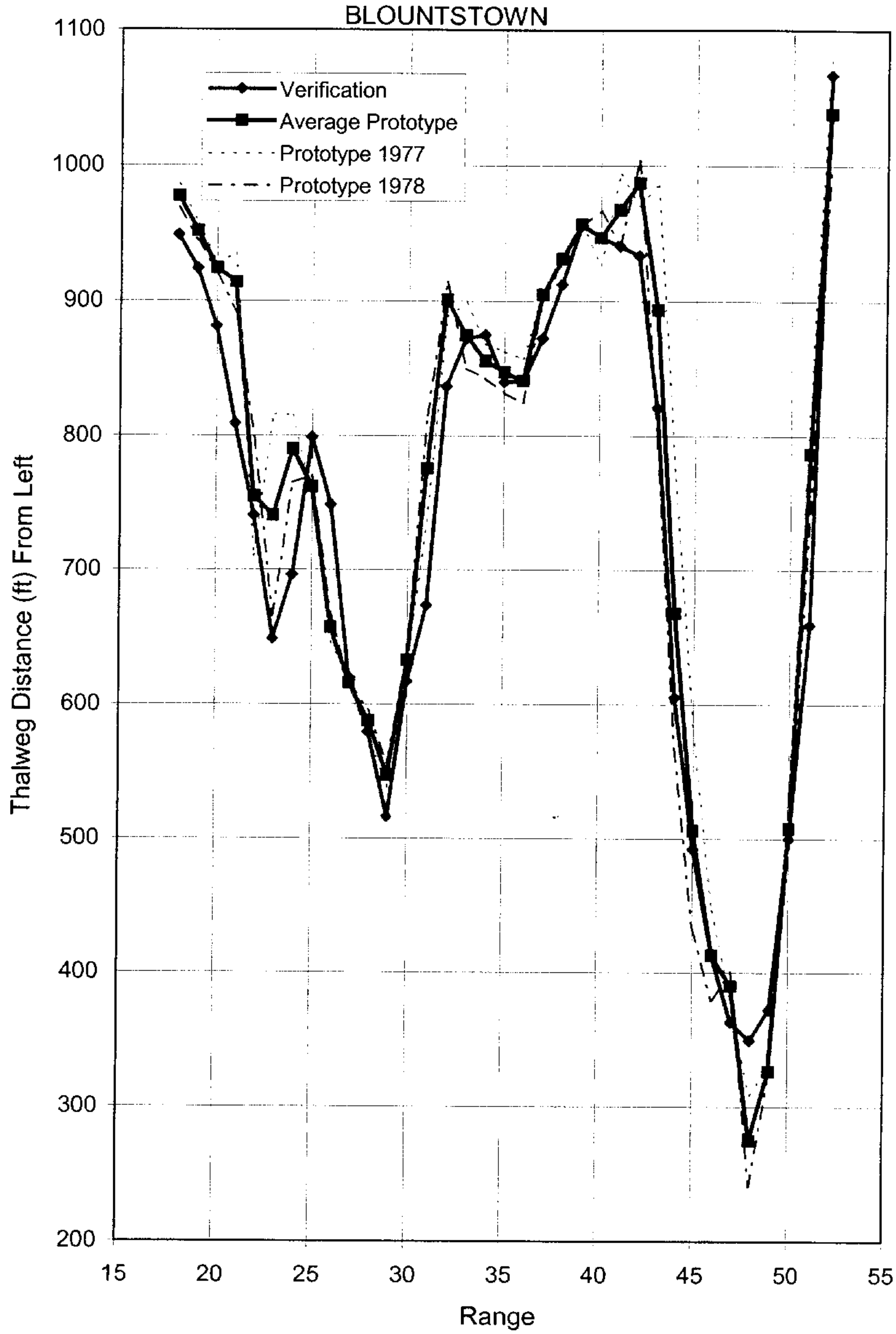

Figure B-2.2a Thalweg Position From Left by Range, Blountstown Reach

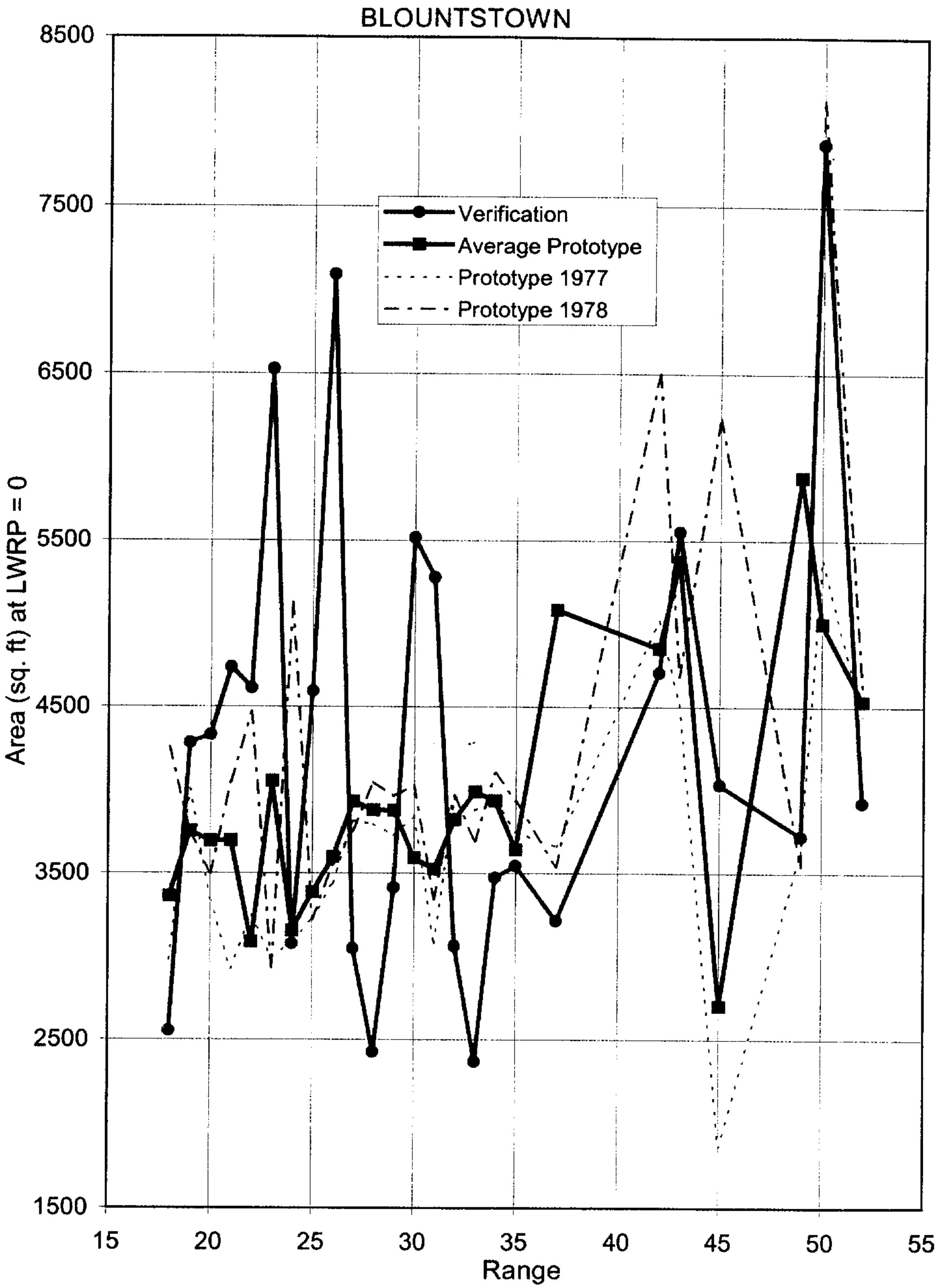

Figure B-2.2b Cross-Section Area by Range, Blountstown Reach

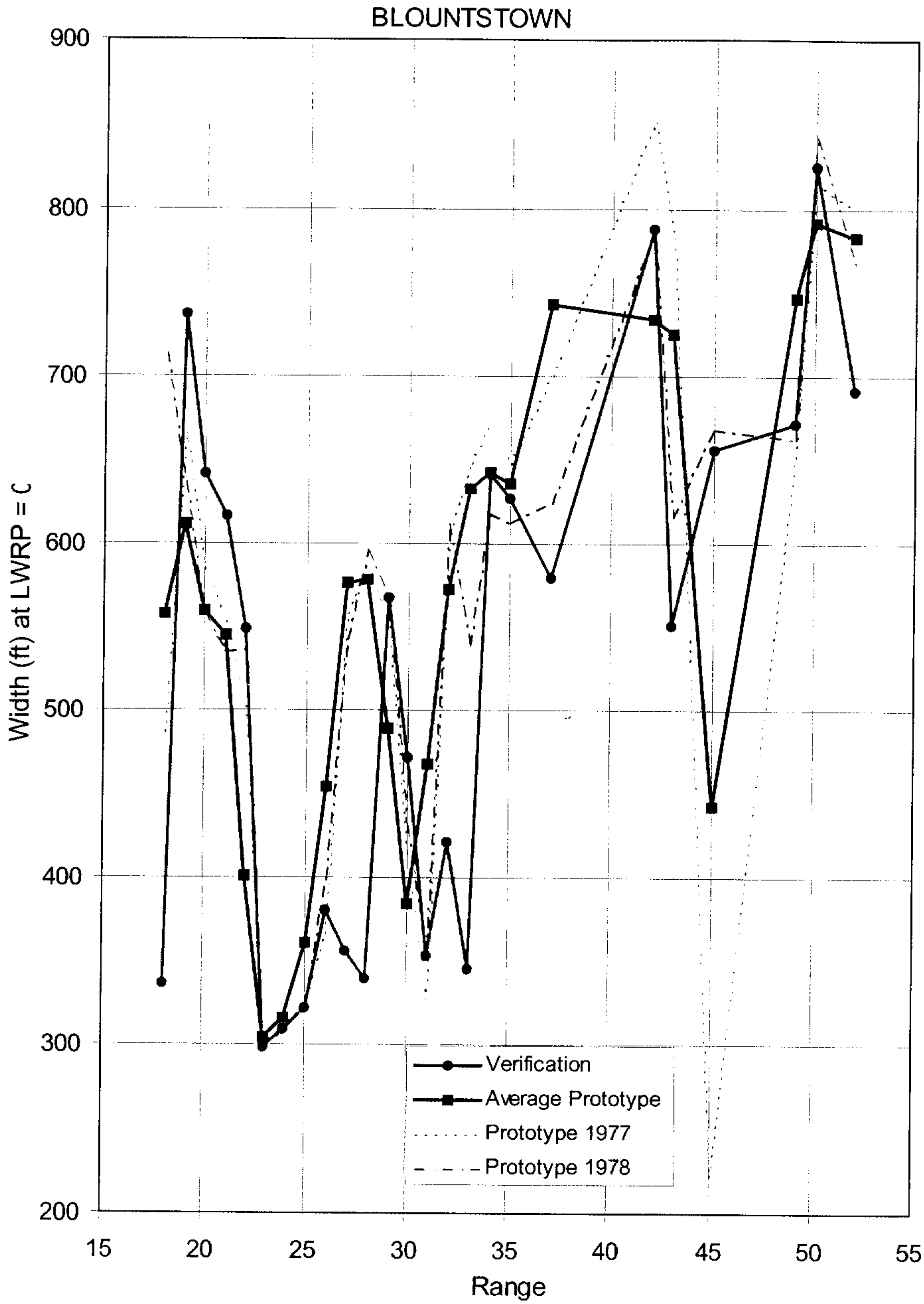

Figure B-2.2c Top Width by Range, Blountstown Reach

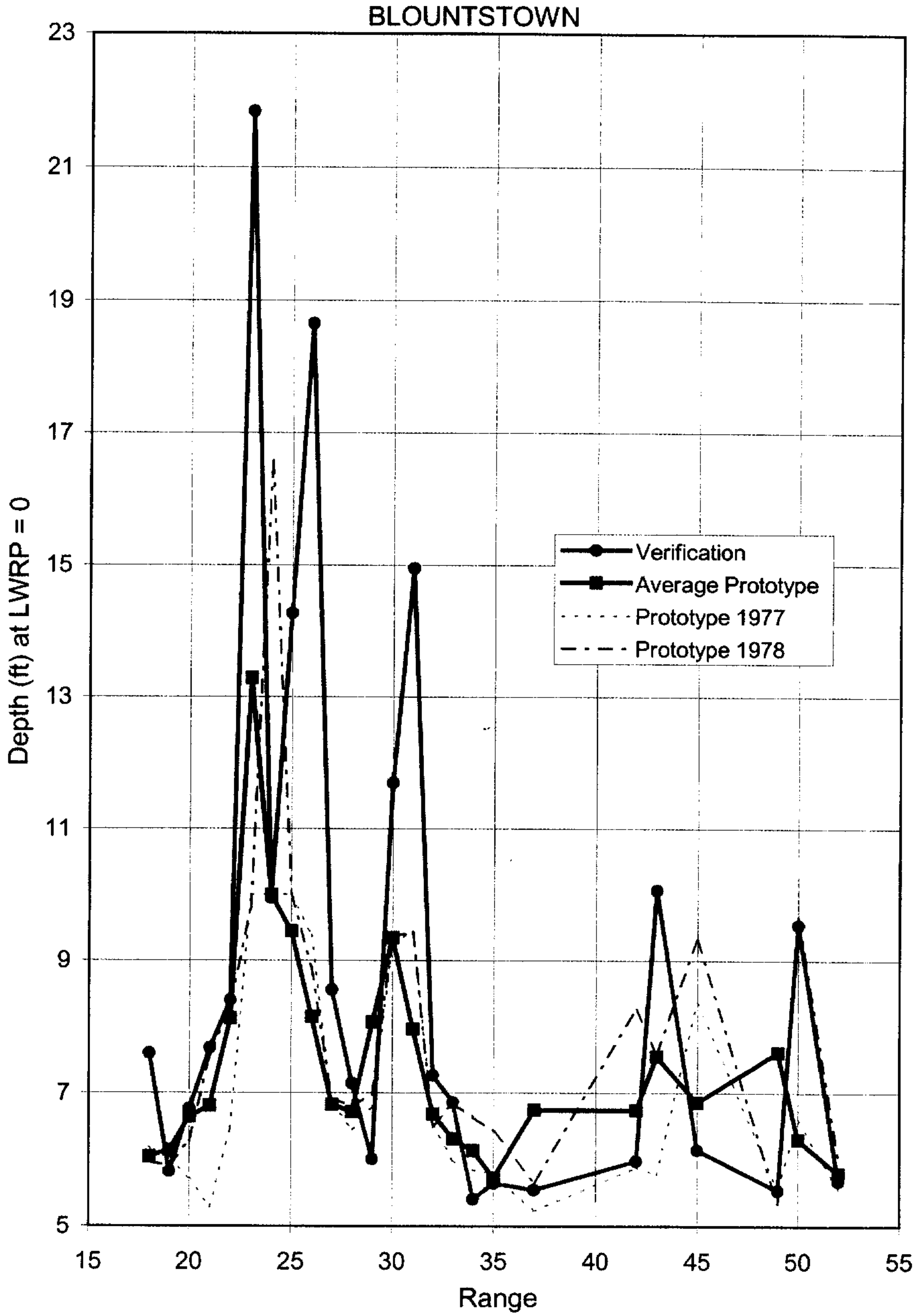

Figure B-2.2d Hydraulic Depth by Range, Blountstown Reach

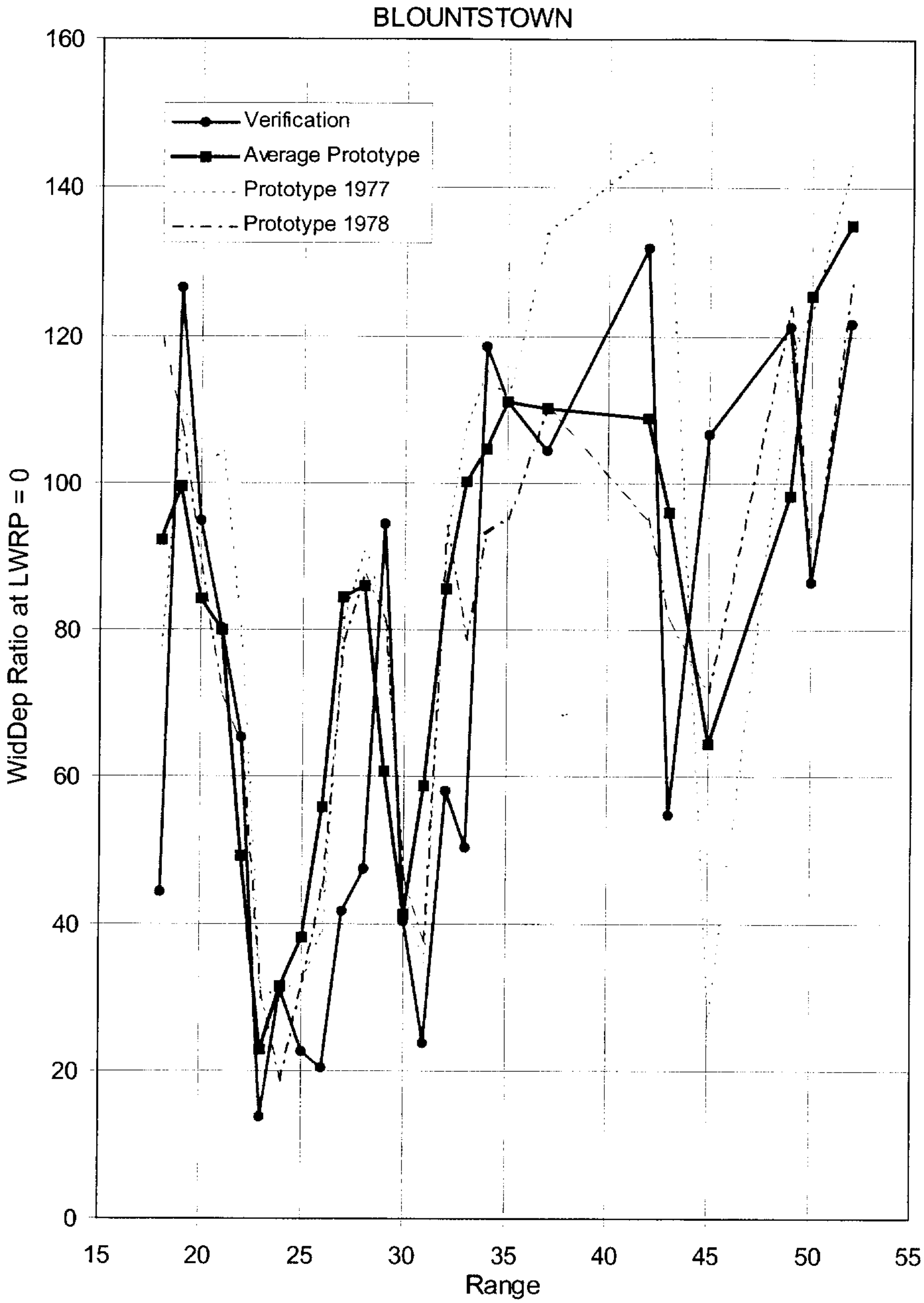

Figure B-2.2e Width/Depth Ratio by Range, Blountstown Reach

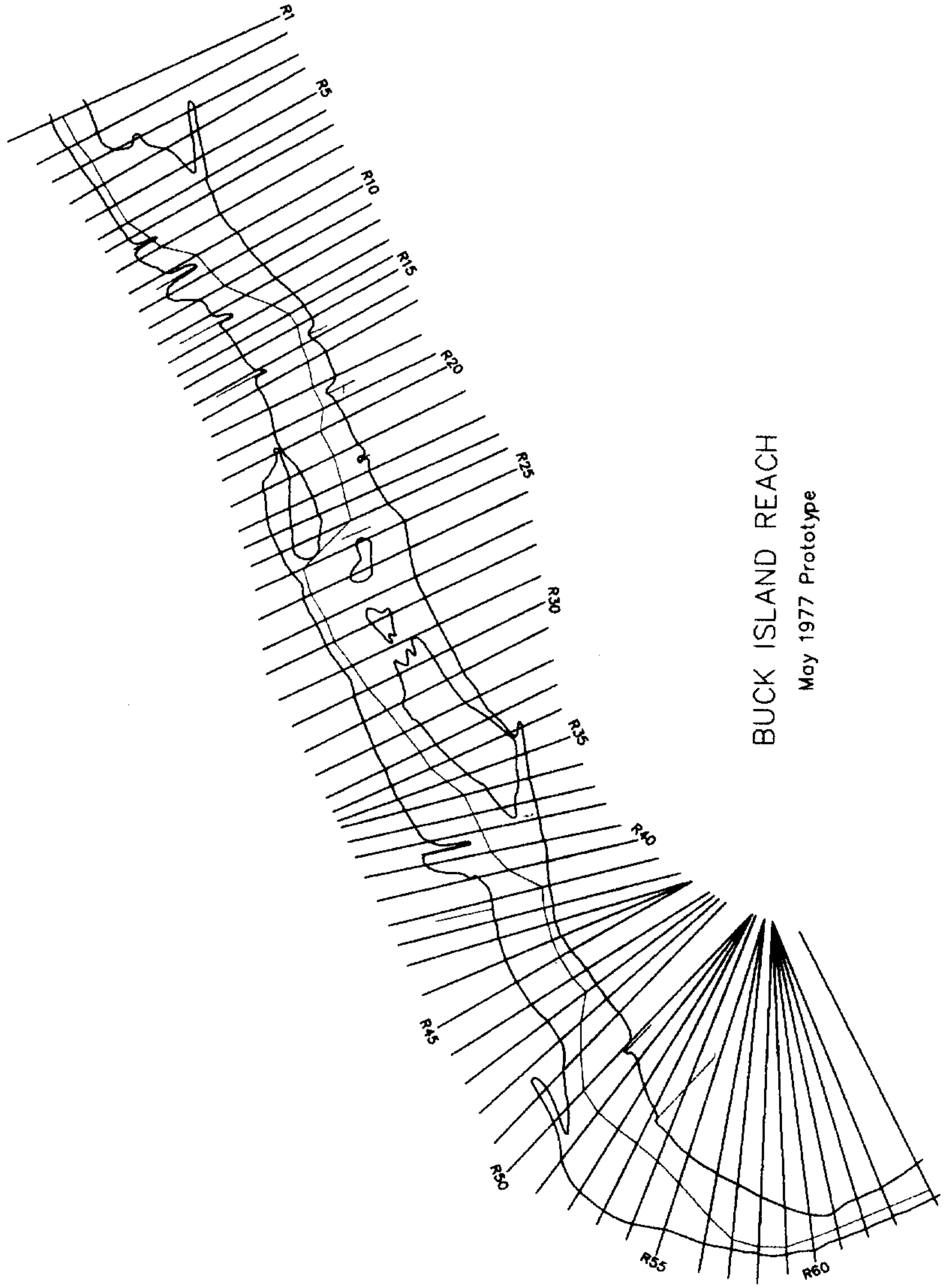

Figure B-3.1a Buck Island Model Plan View

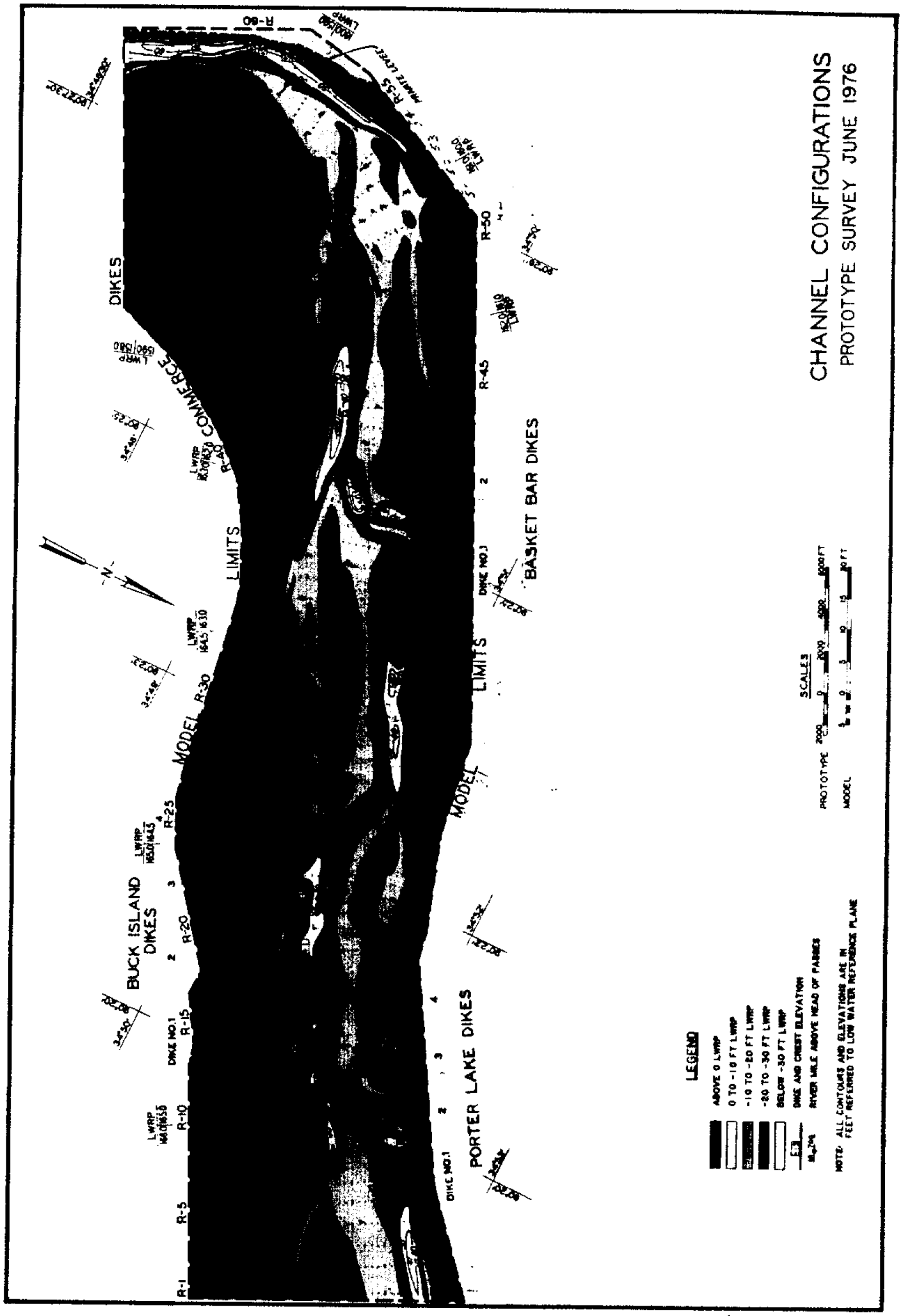

Figure B-3.1b Buck Island June 1976 Prototype Survey

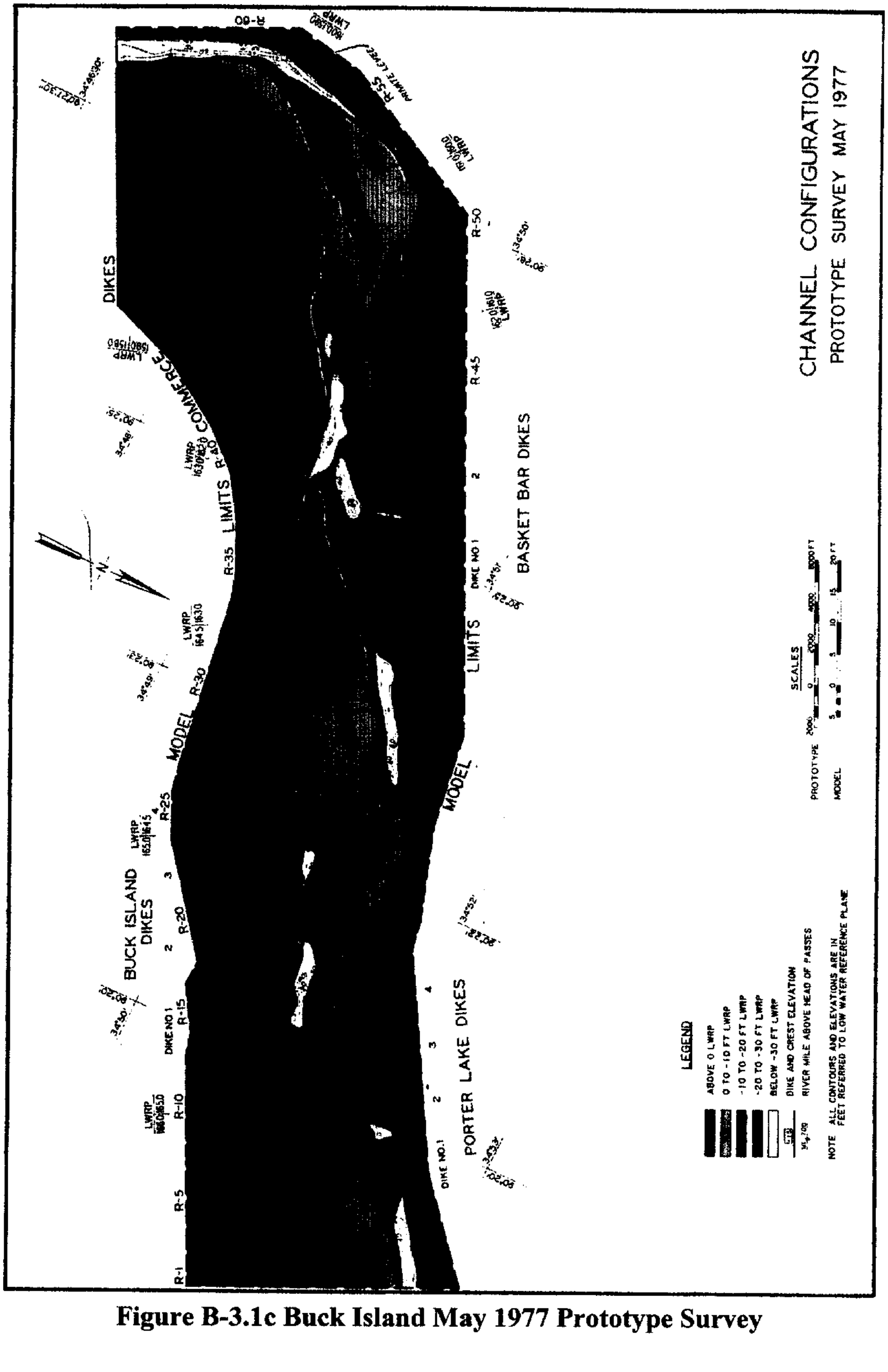

Figure B-3.1c Buck Island May 1977 Prototype Survey

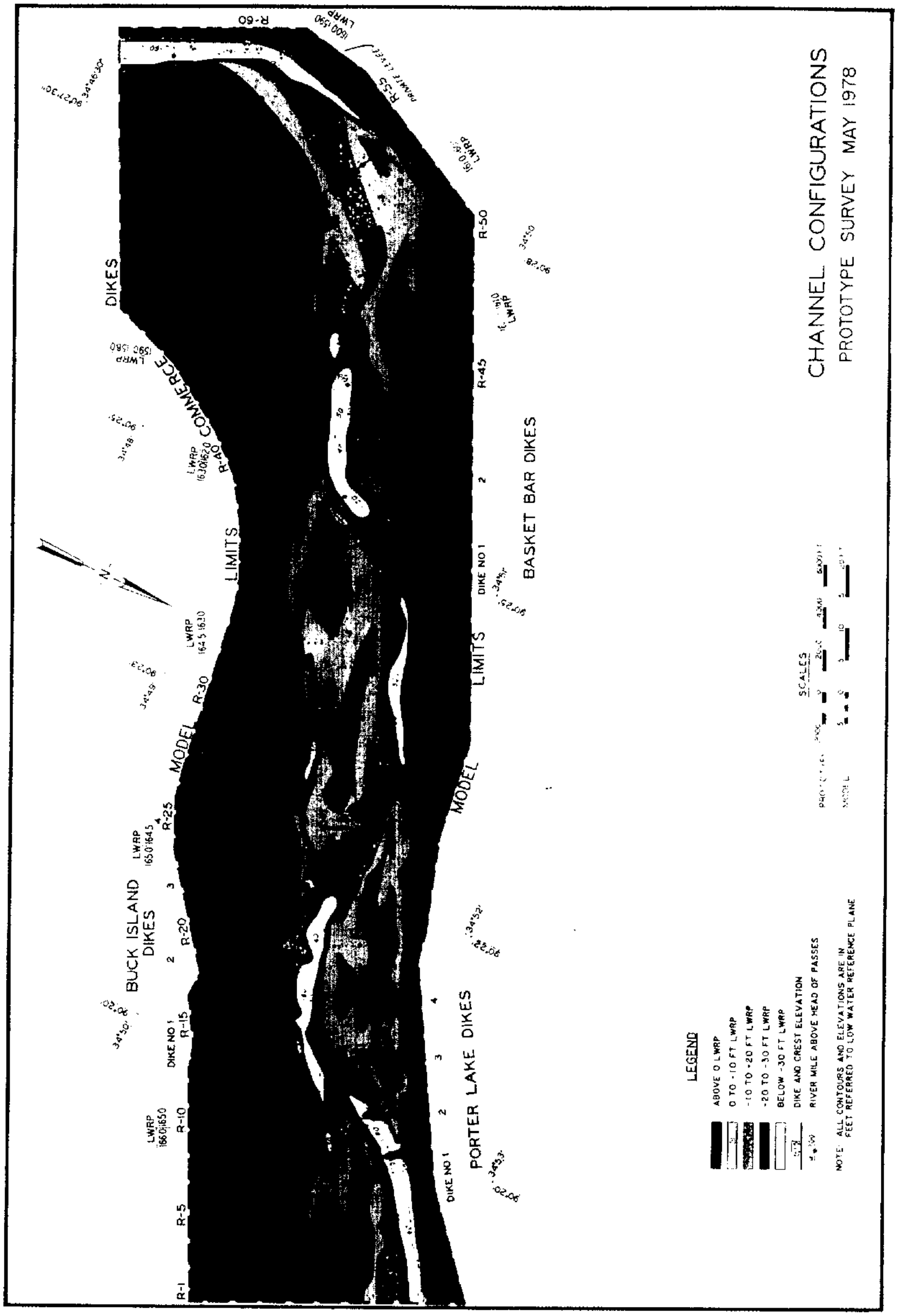

Figure B-3.1d Buck Island May 1978 Prototype Survey

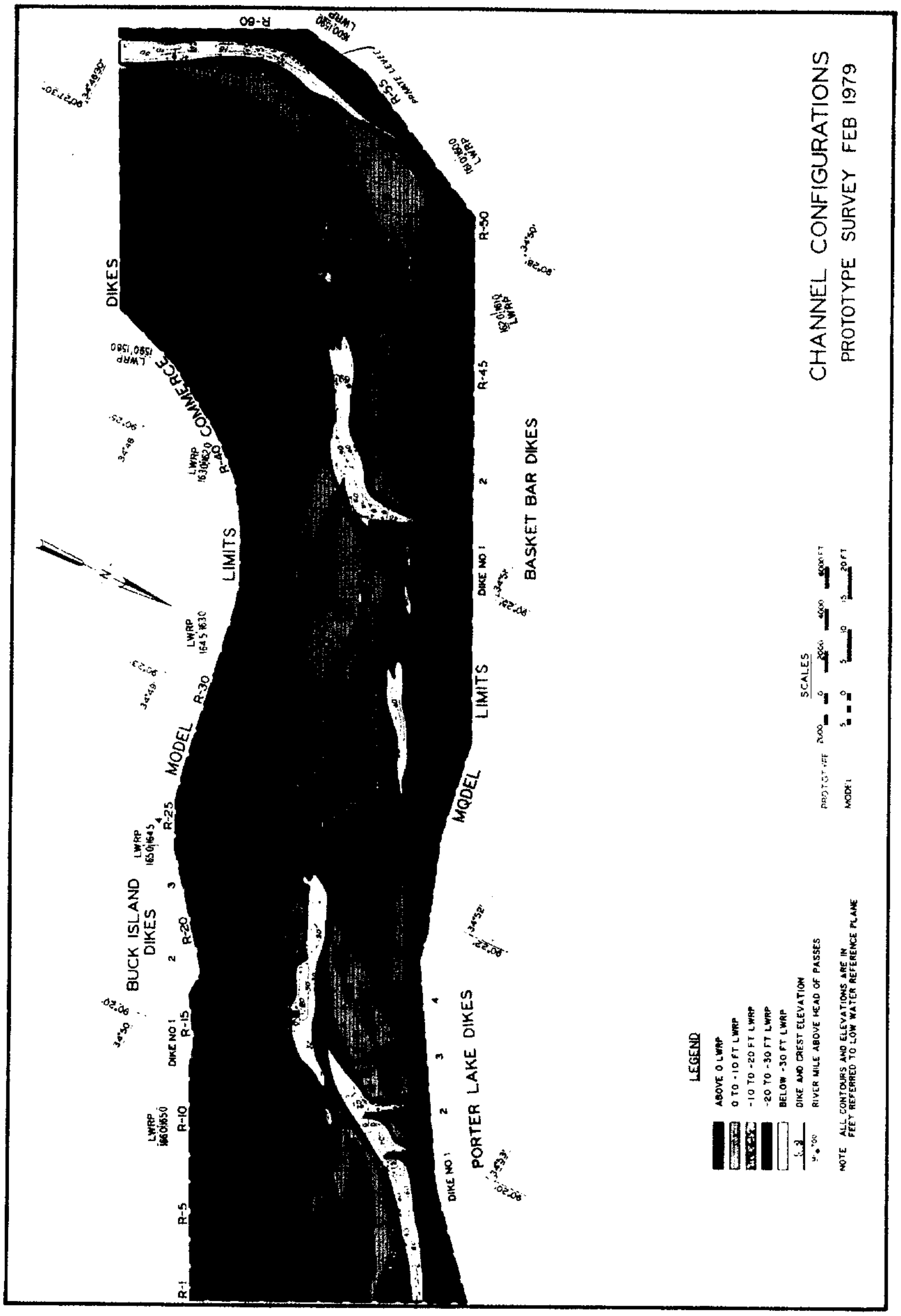

Figure B-3.1e Buck Island February 1979 Prototype Survey

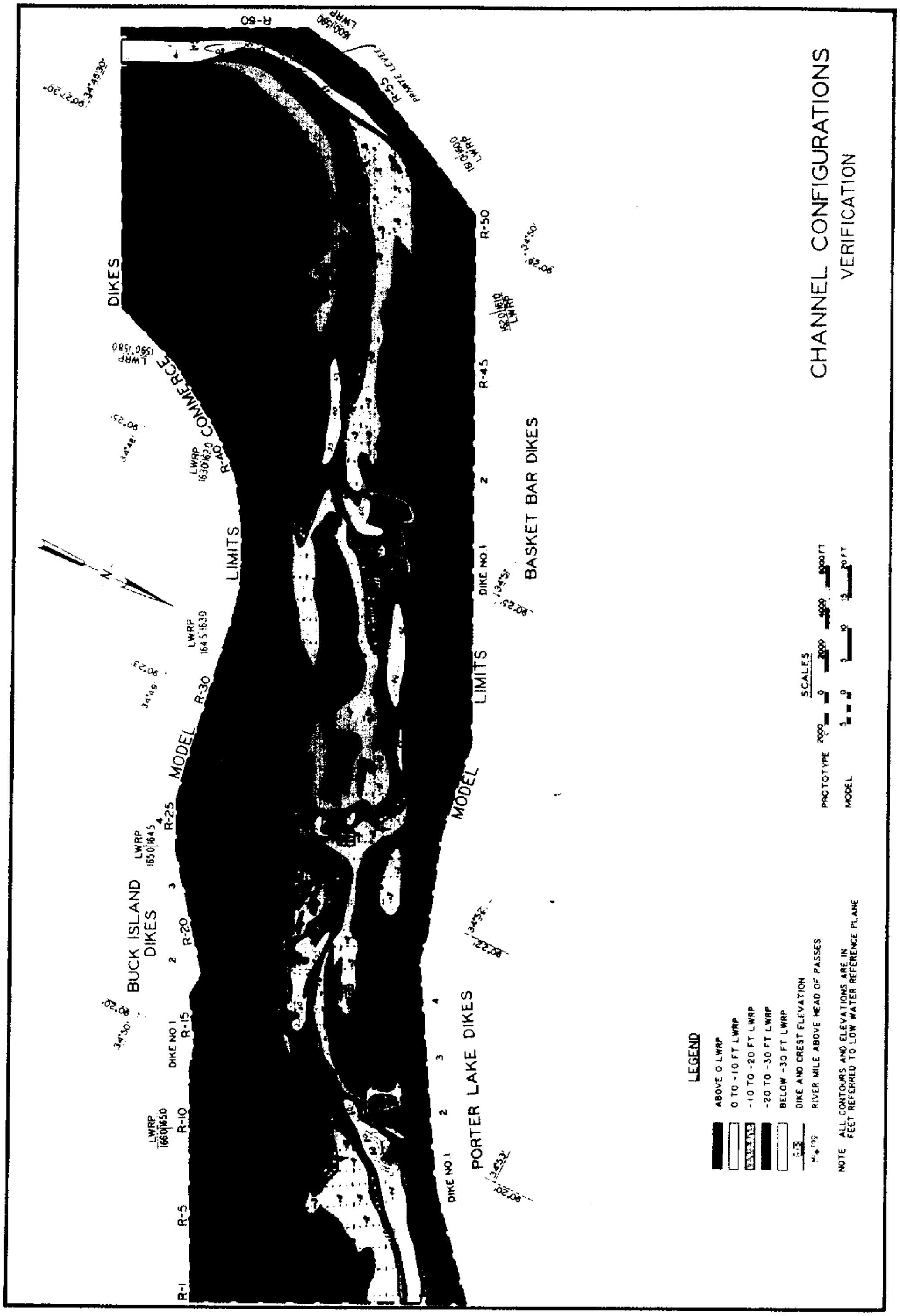

Figure B-3.1f Buck Island Verification Test Survey

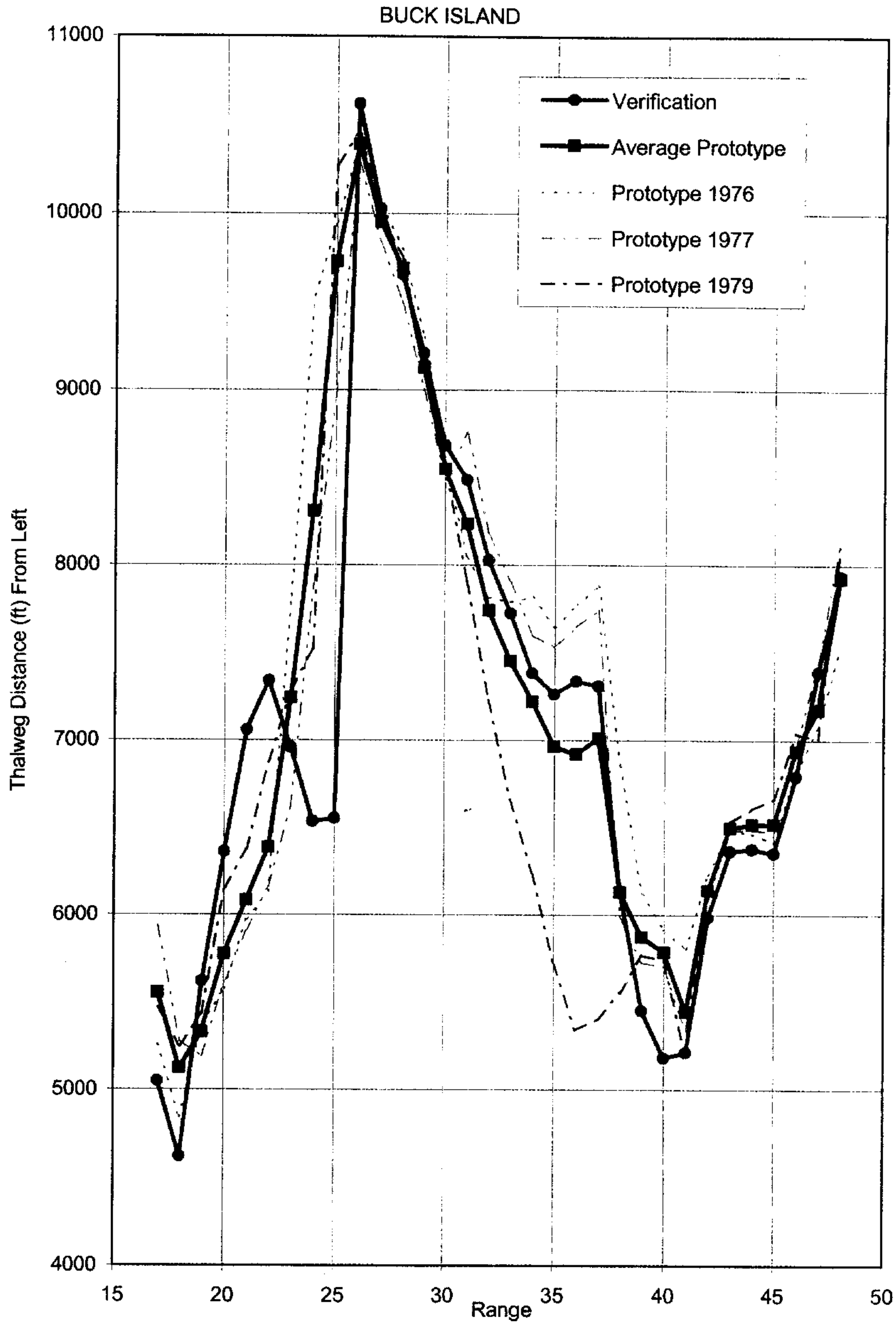

Figure B-3.2a Thawleg Position From Left by Range, Buck Island

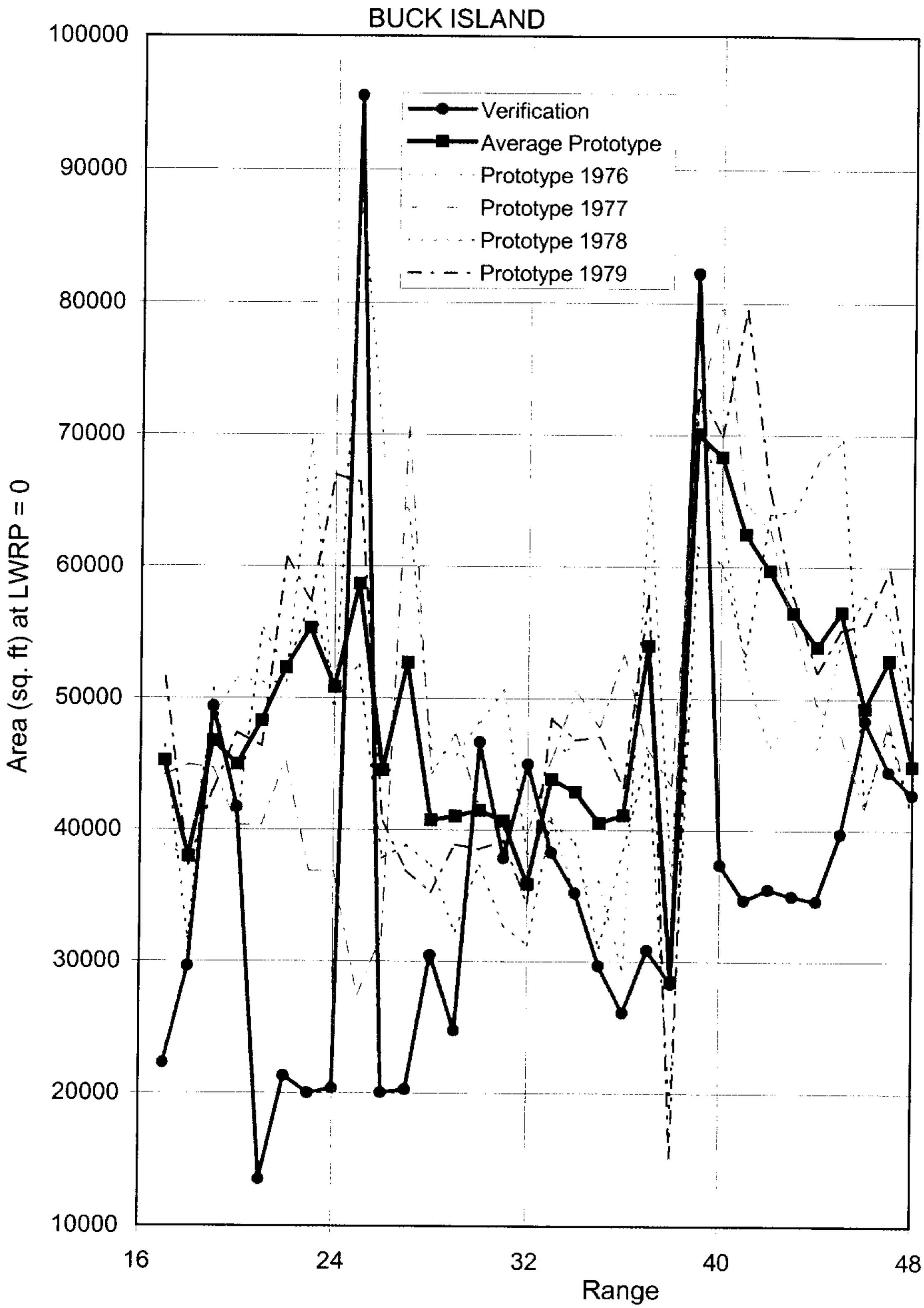

Figure B-3.2b Cross-Section Area by Range, Buck Island

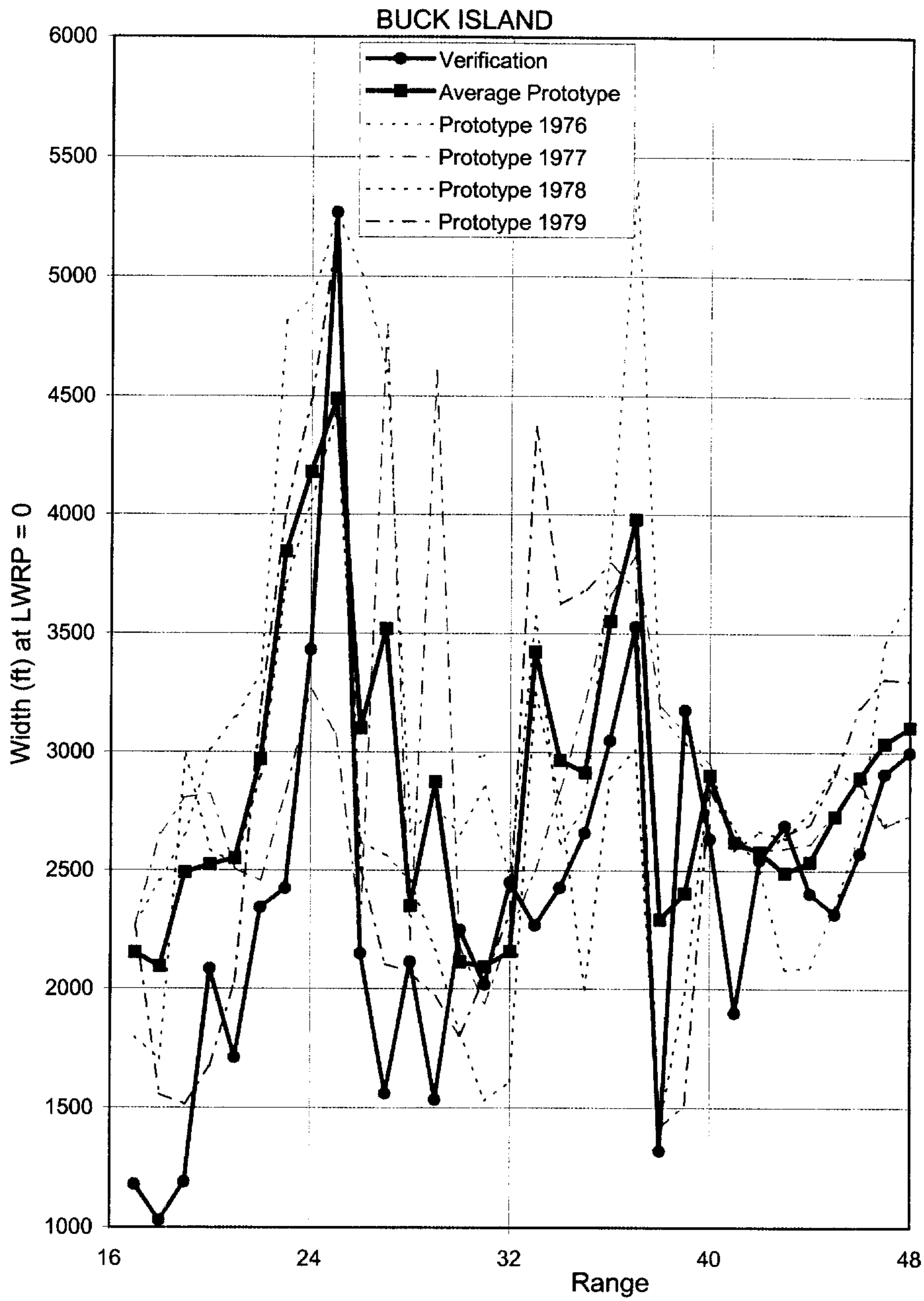

Figure B-3.2c Top Width by Range, Buck Island

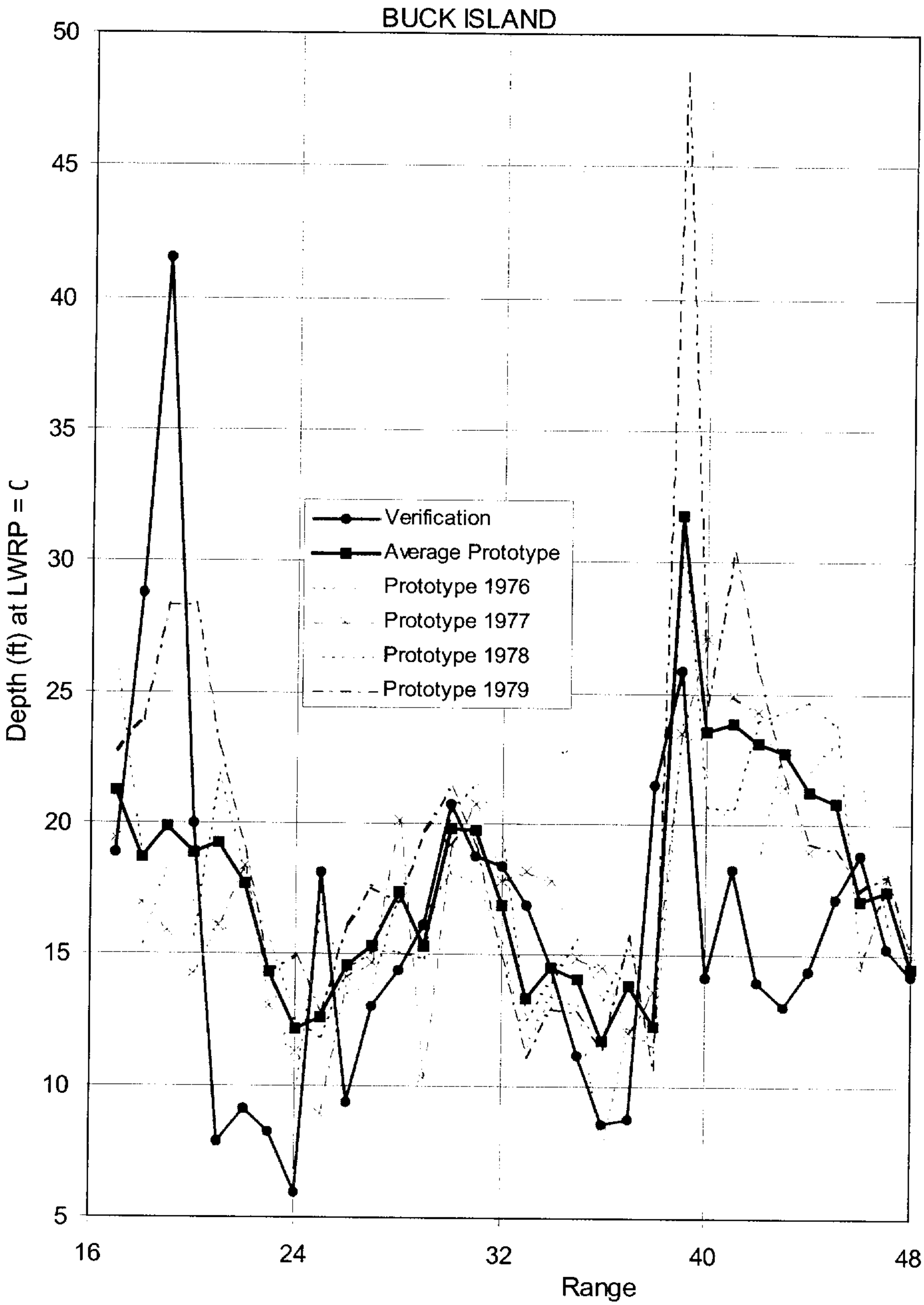

Figure B-3.2d Hydraulic Depth by Range, Buck Island

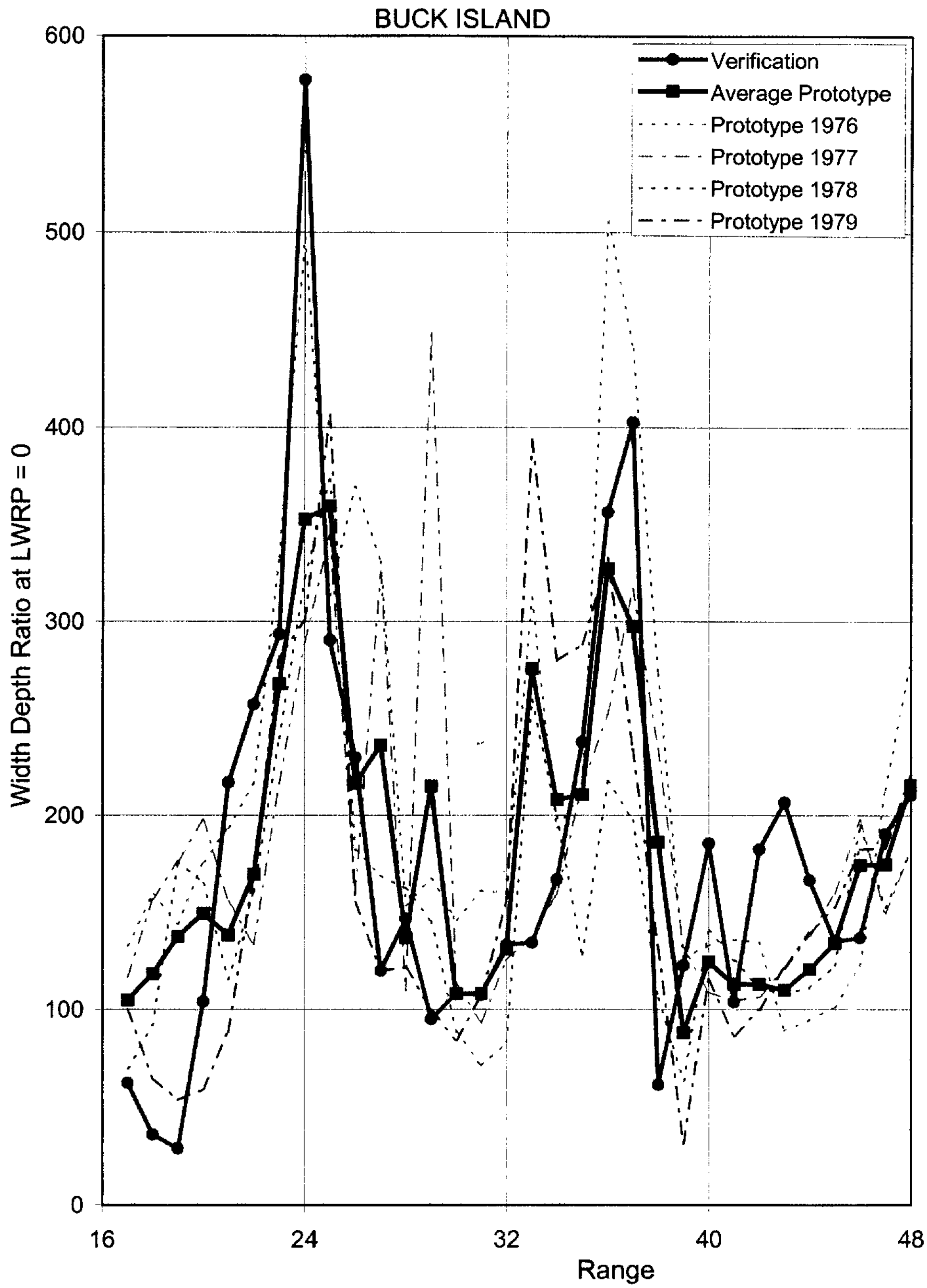

Figure B-3.2e Width/Depth Ratio by Range, Buck Island

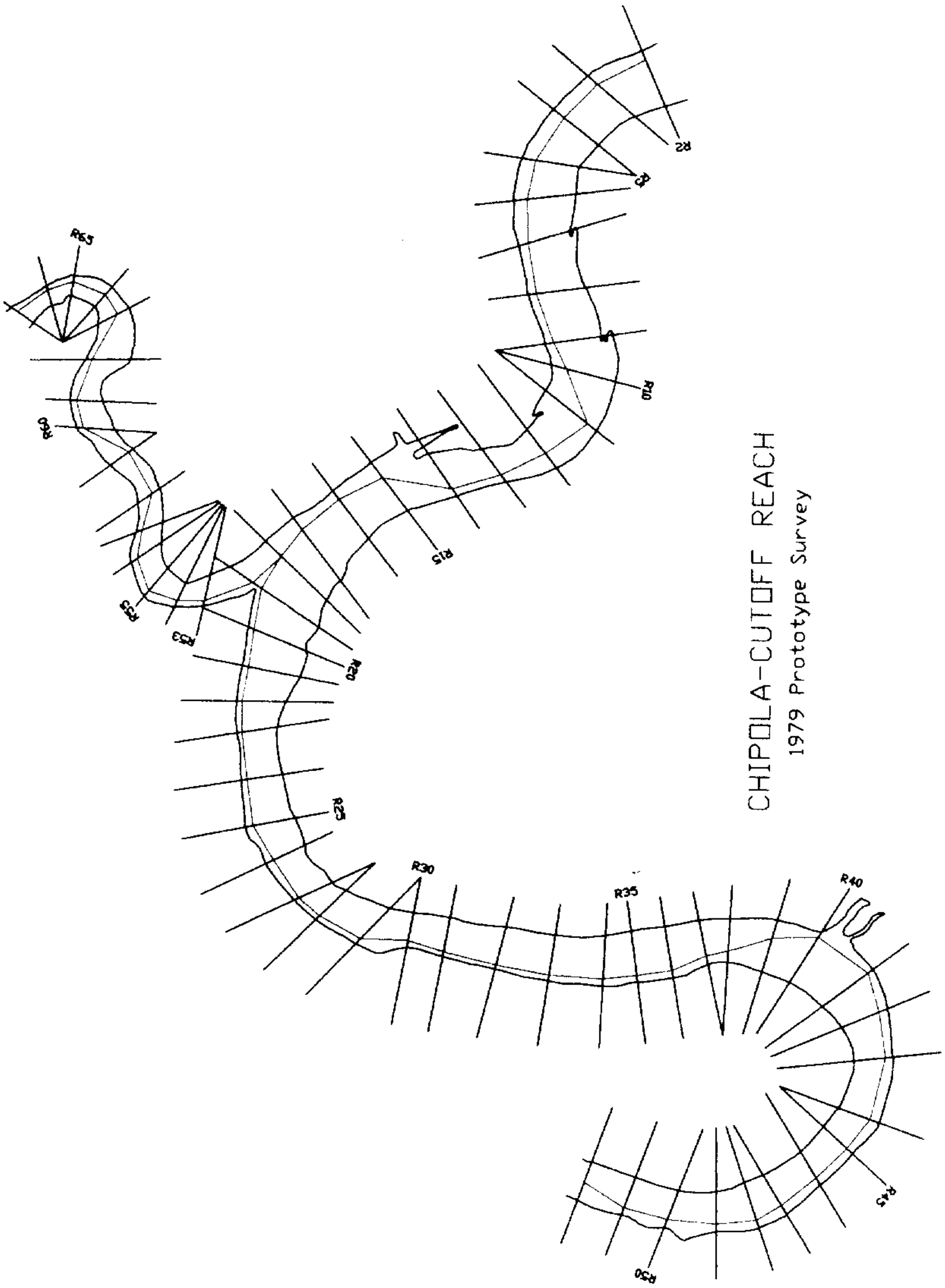

Figure B-4.1a Chipola-Cutoff Model Plan View

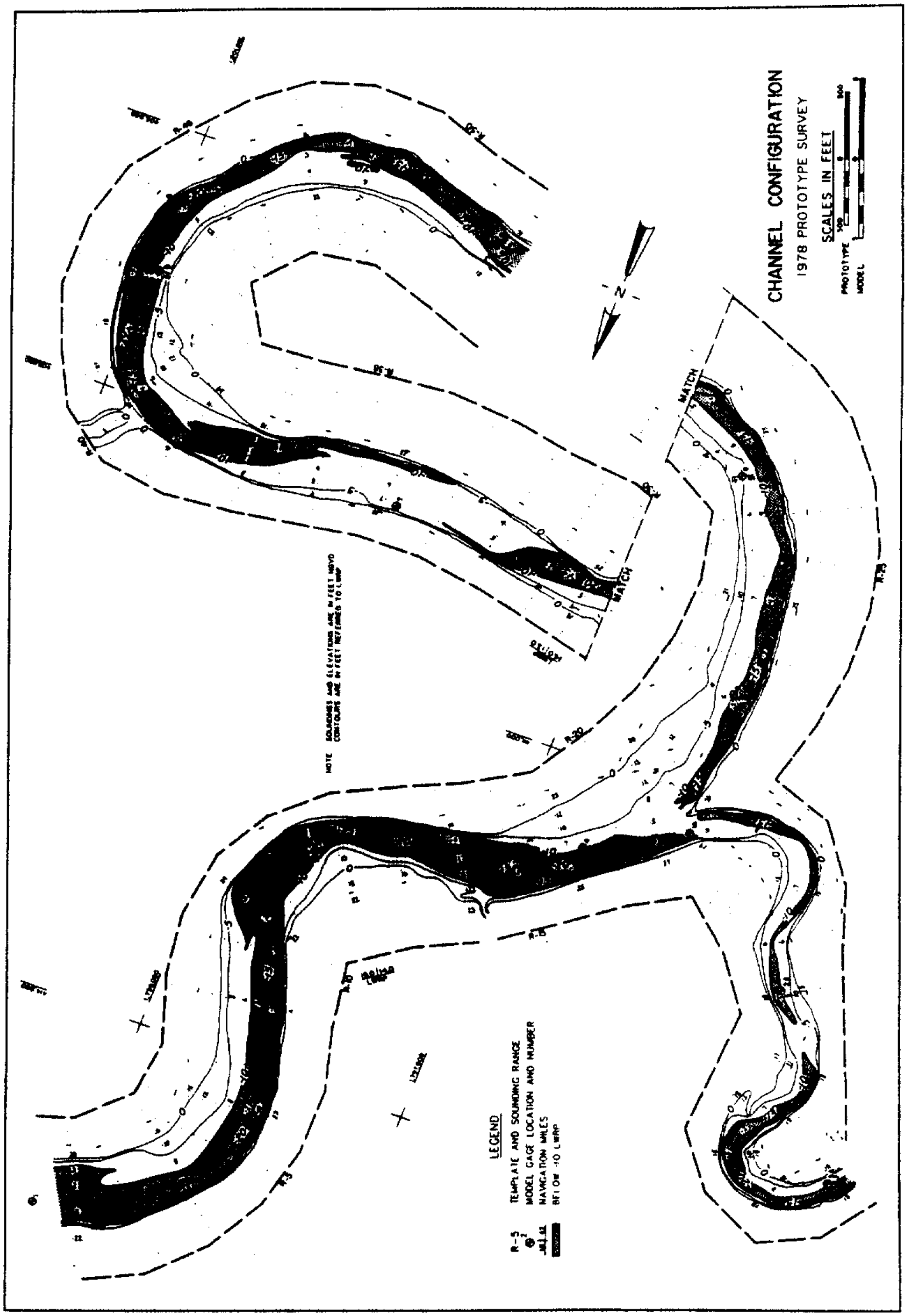

Figure B-4.1b Chipola-Cutoff January 1978 Prototype Survey

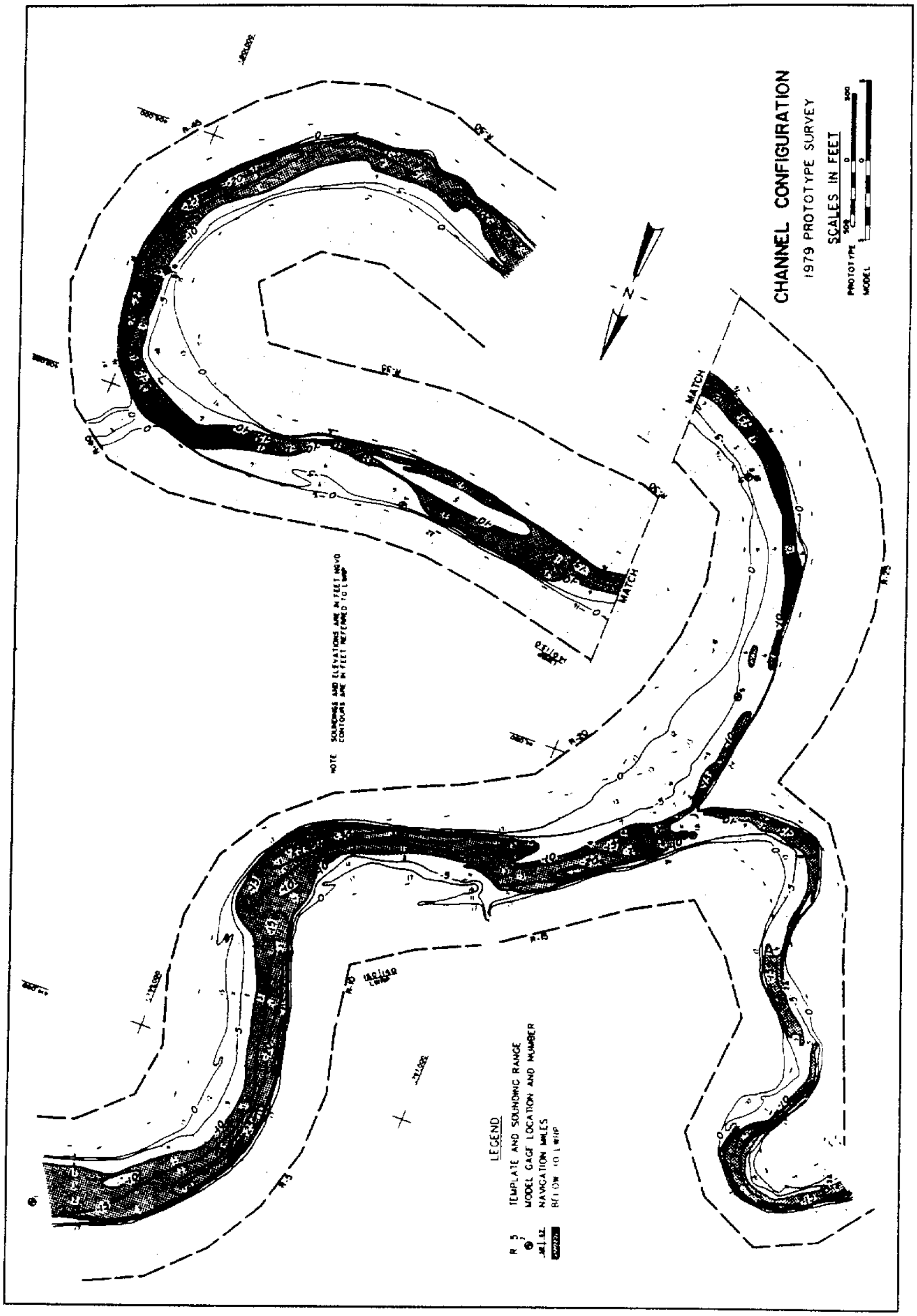

Figure B-4.1c Chipola-Cutoff June 1979 Prototype Survey

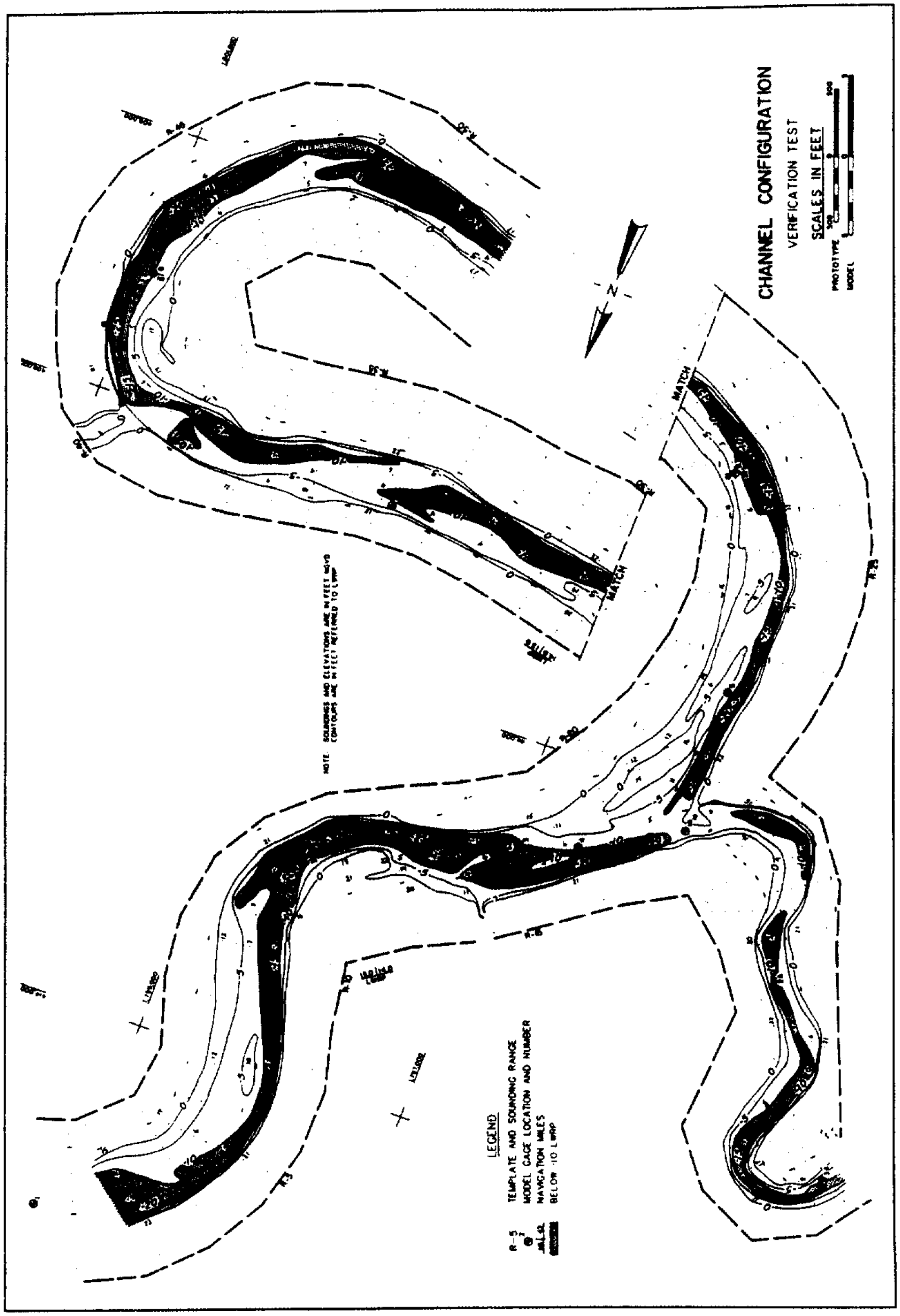

Figure B-4.1d Chipola-Cutoff Verification Test Survey

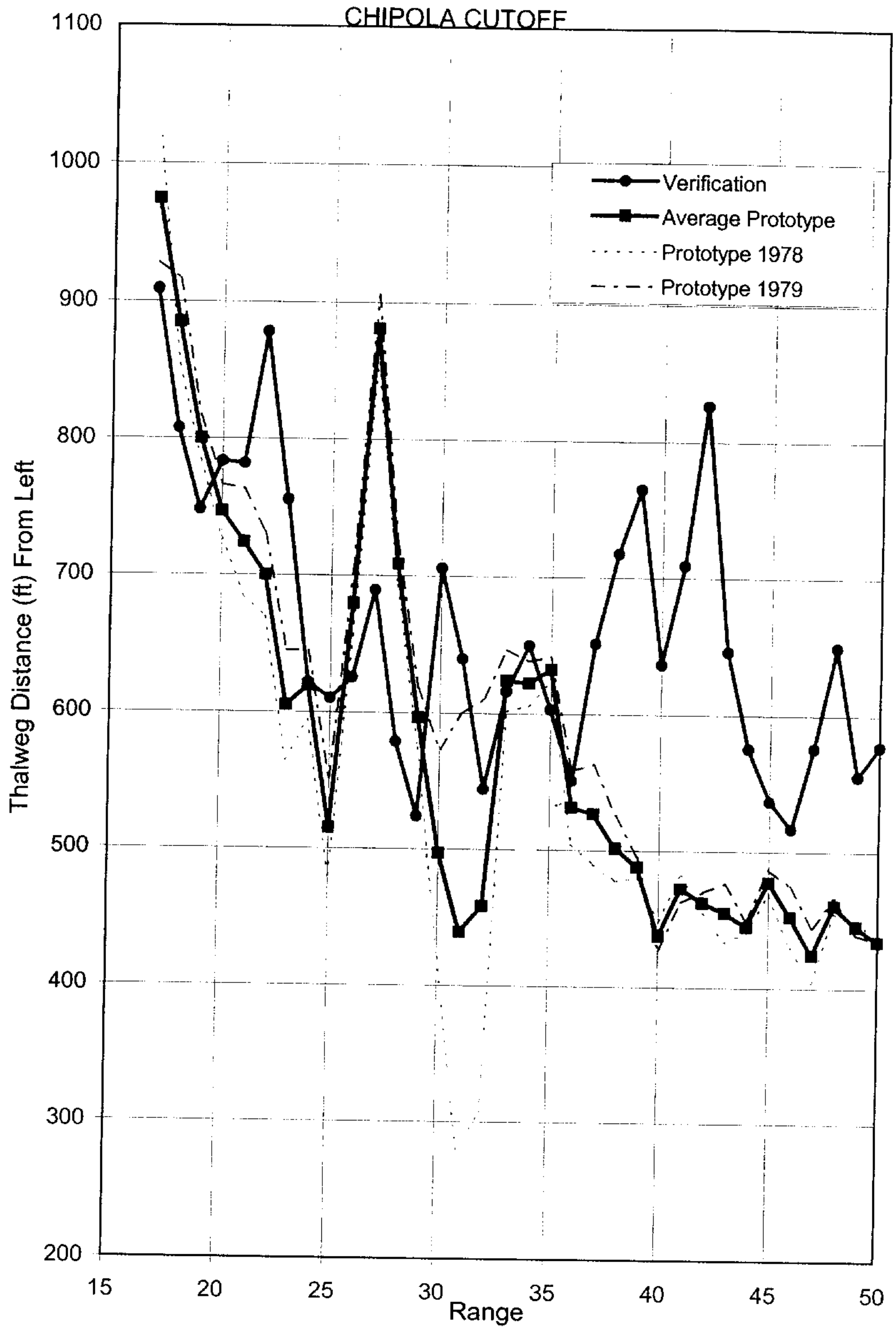

Figure B-4.2a Thalweg Position From Left by Range, Chipola Cutoff

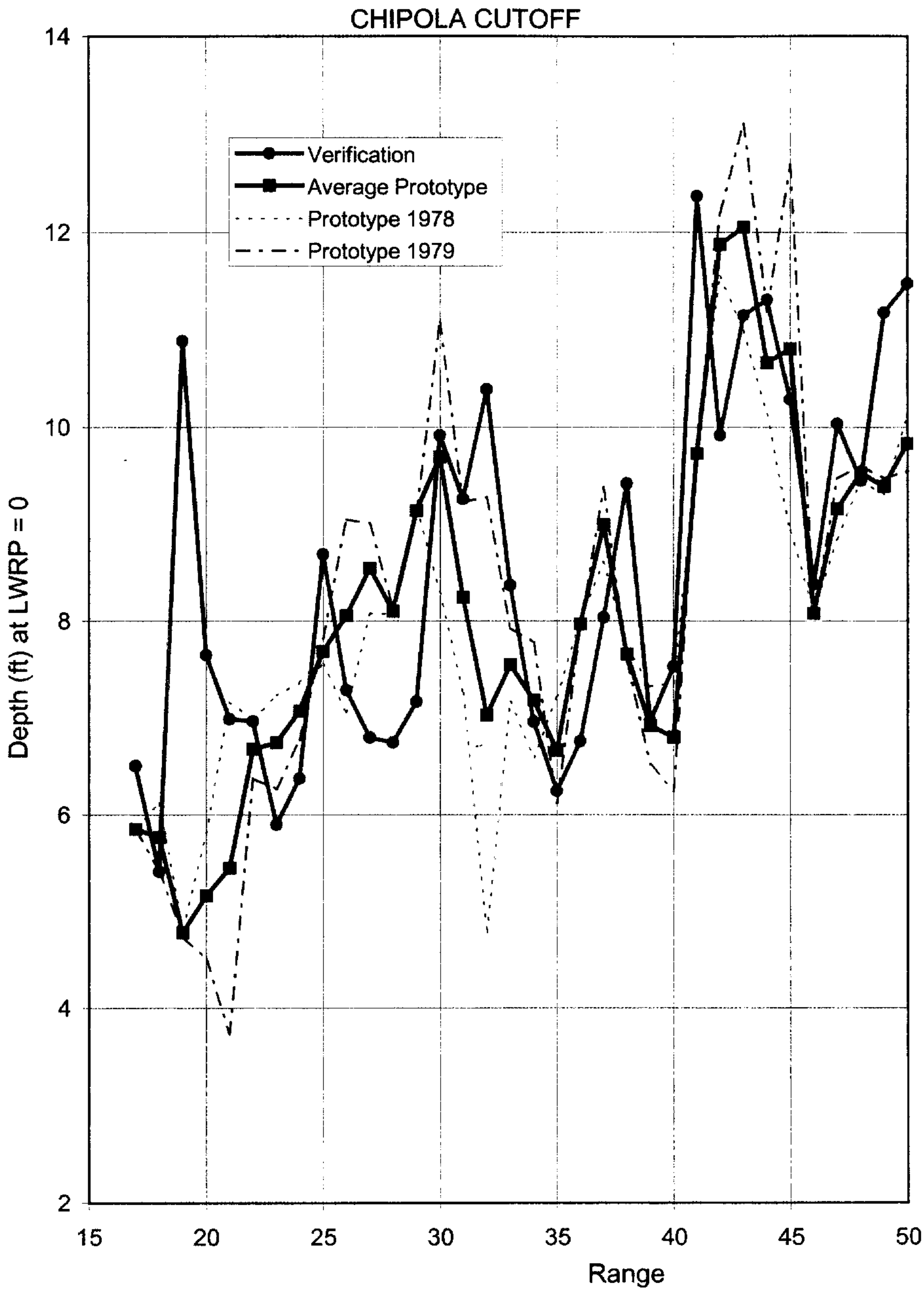

Figure B-4.2d Hydraulic Depth by Range, Chipola Cutoff

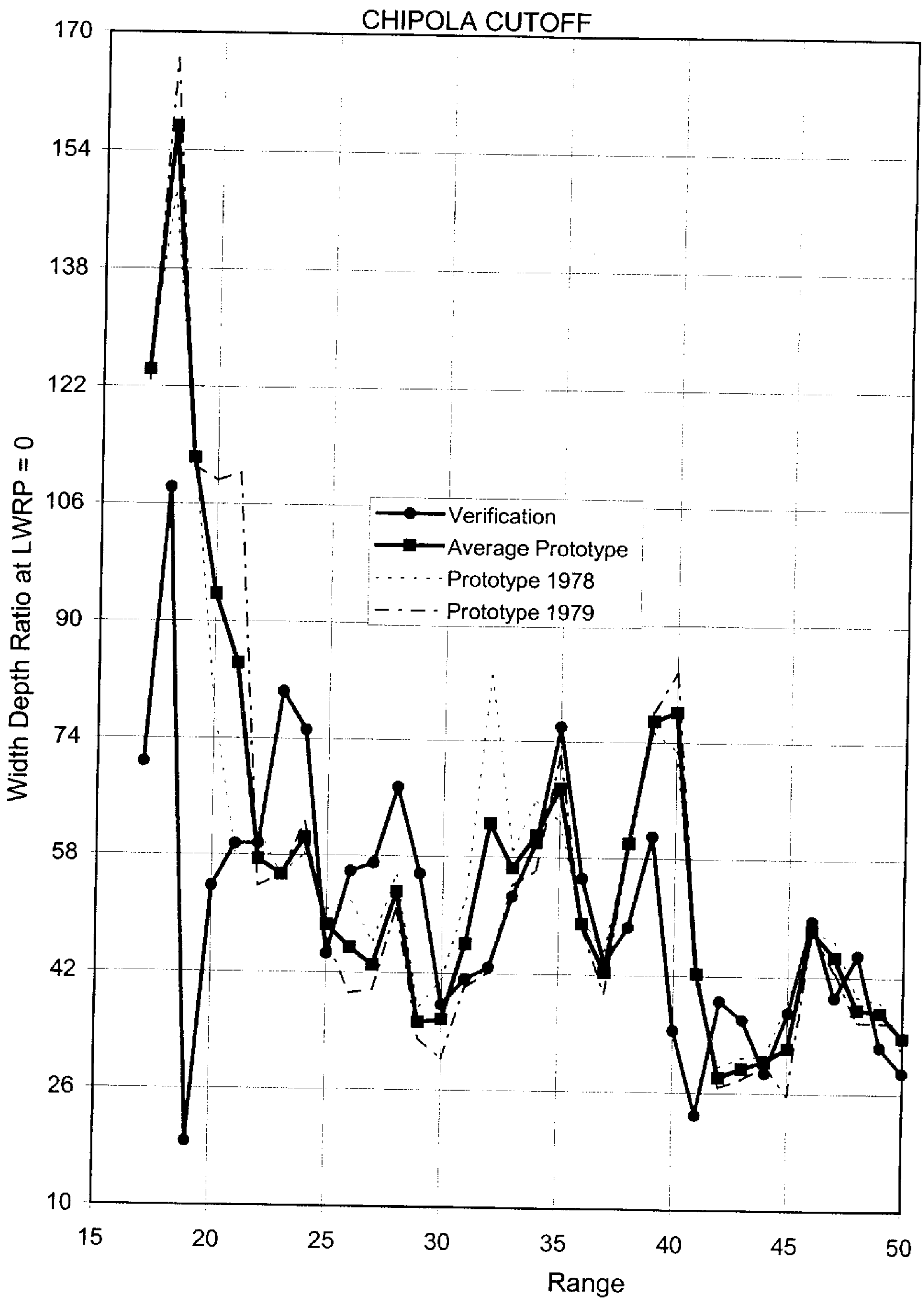

Figure B-4.2e Width/Depth Ratio by Range, Chipola Cutoff

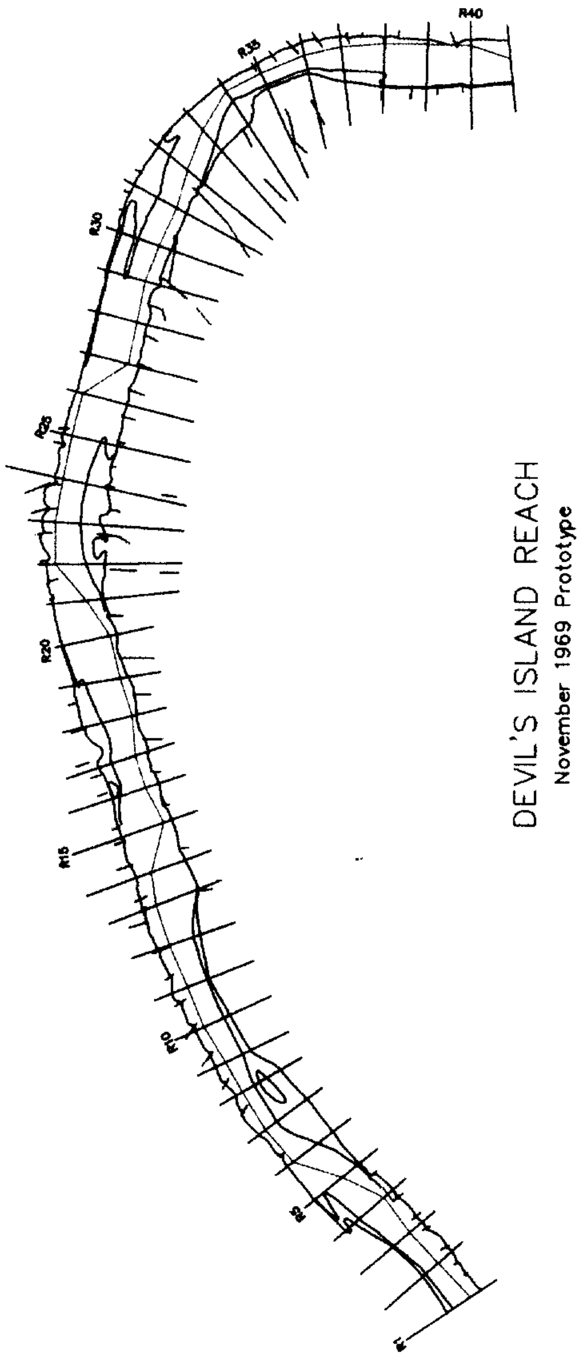

Figure B-5.1a Devil's Island Model Plan View

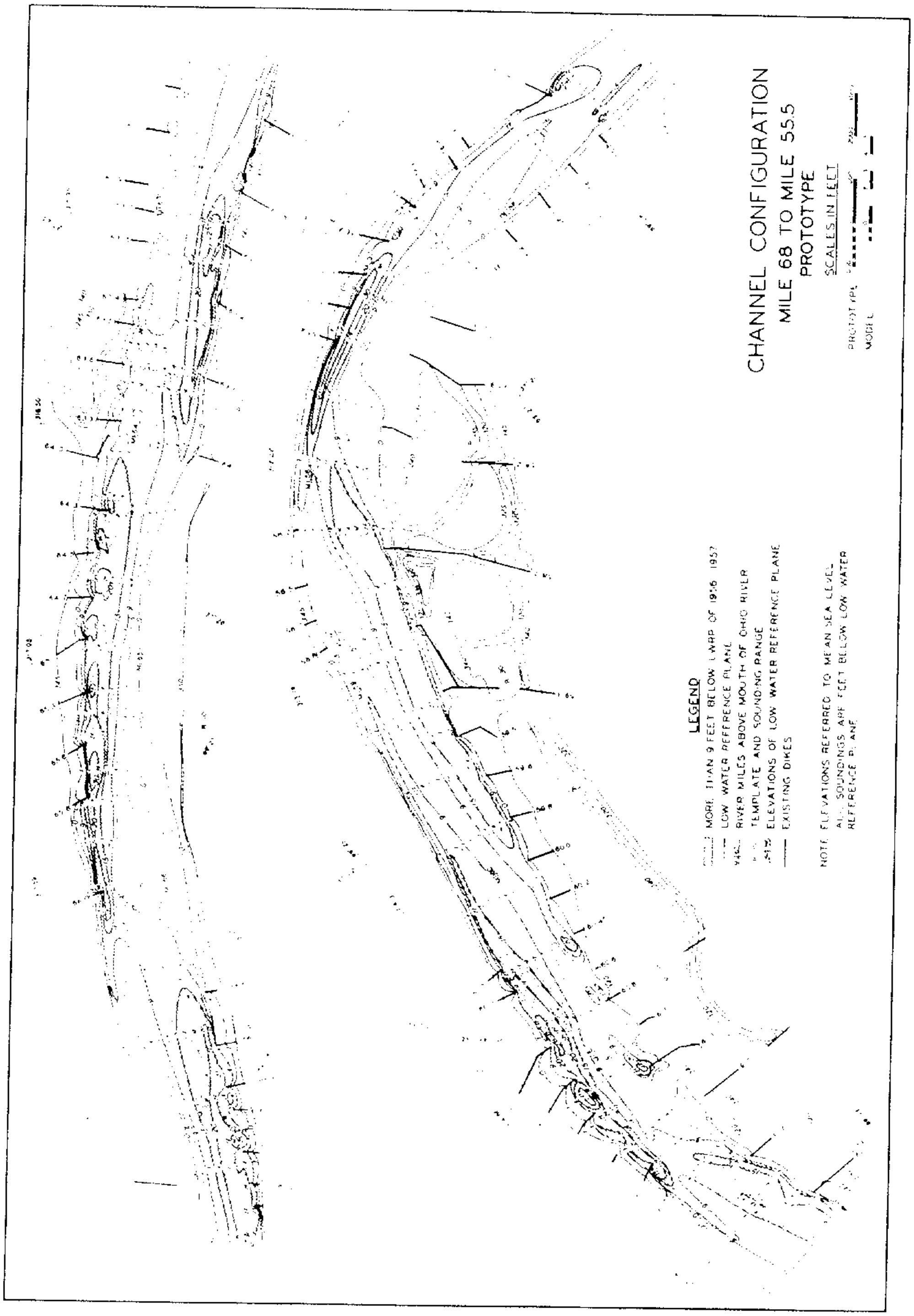

Figure B-5.1b Devil's Island November 1969 Prototype Survey

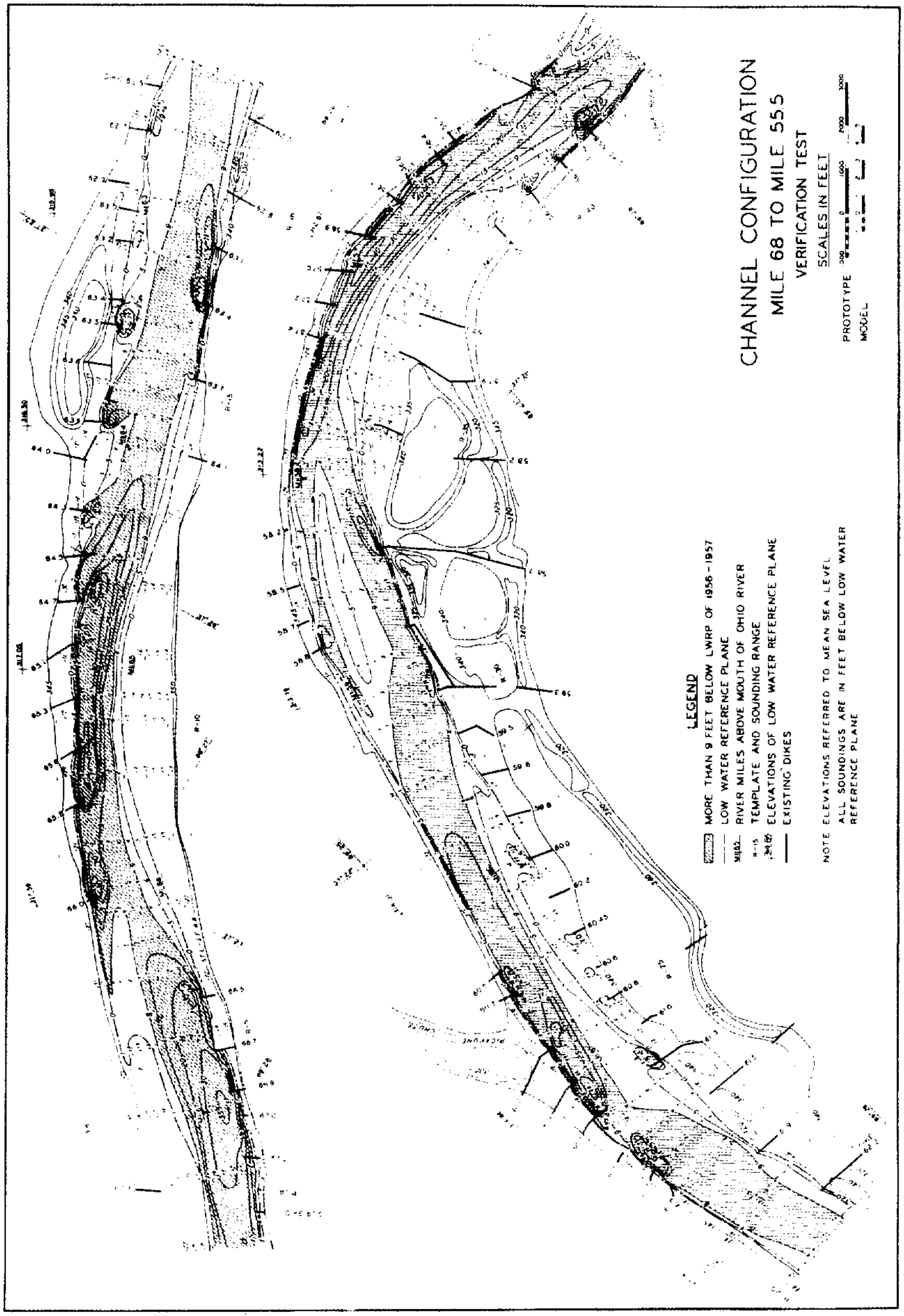

Figure B-5.1c Devil's Island Verification Test Survey

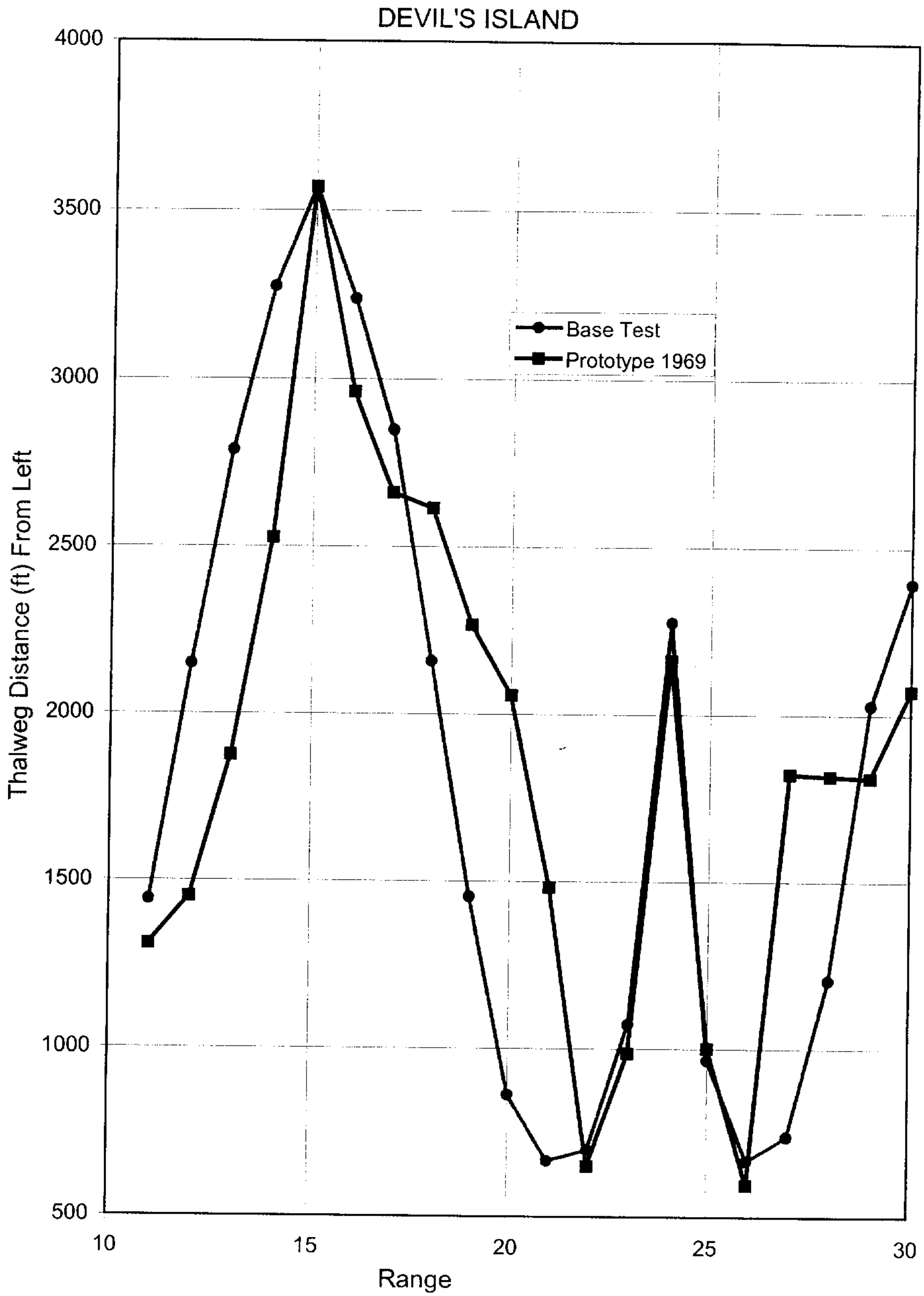

Figure B-5.2a Thalweg Position From Left by Range, Devil's Island

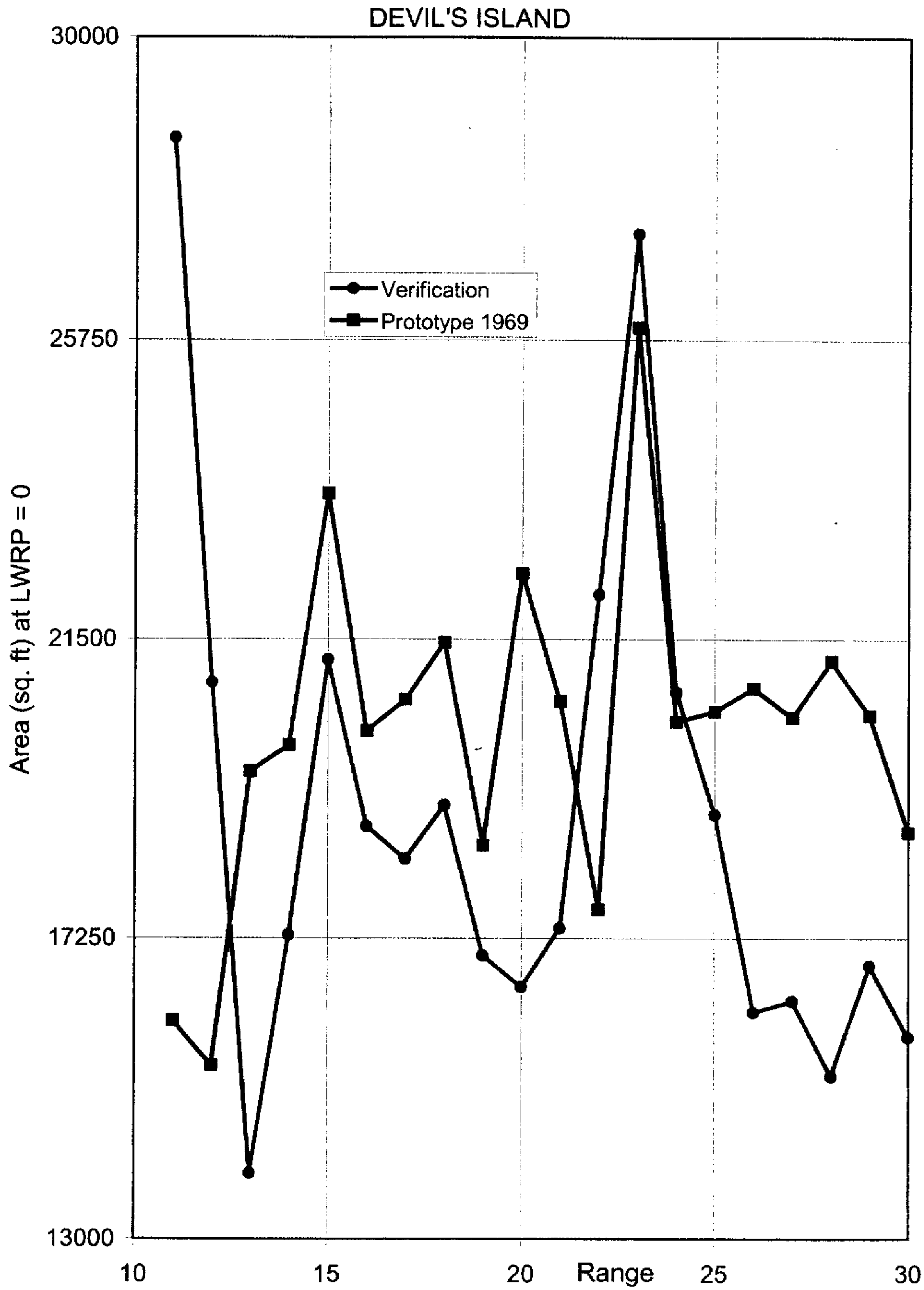

Figure B-5.2b Cross-Section Area by Range, Devil's Island

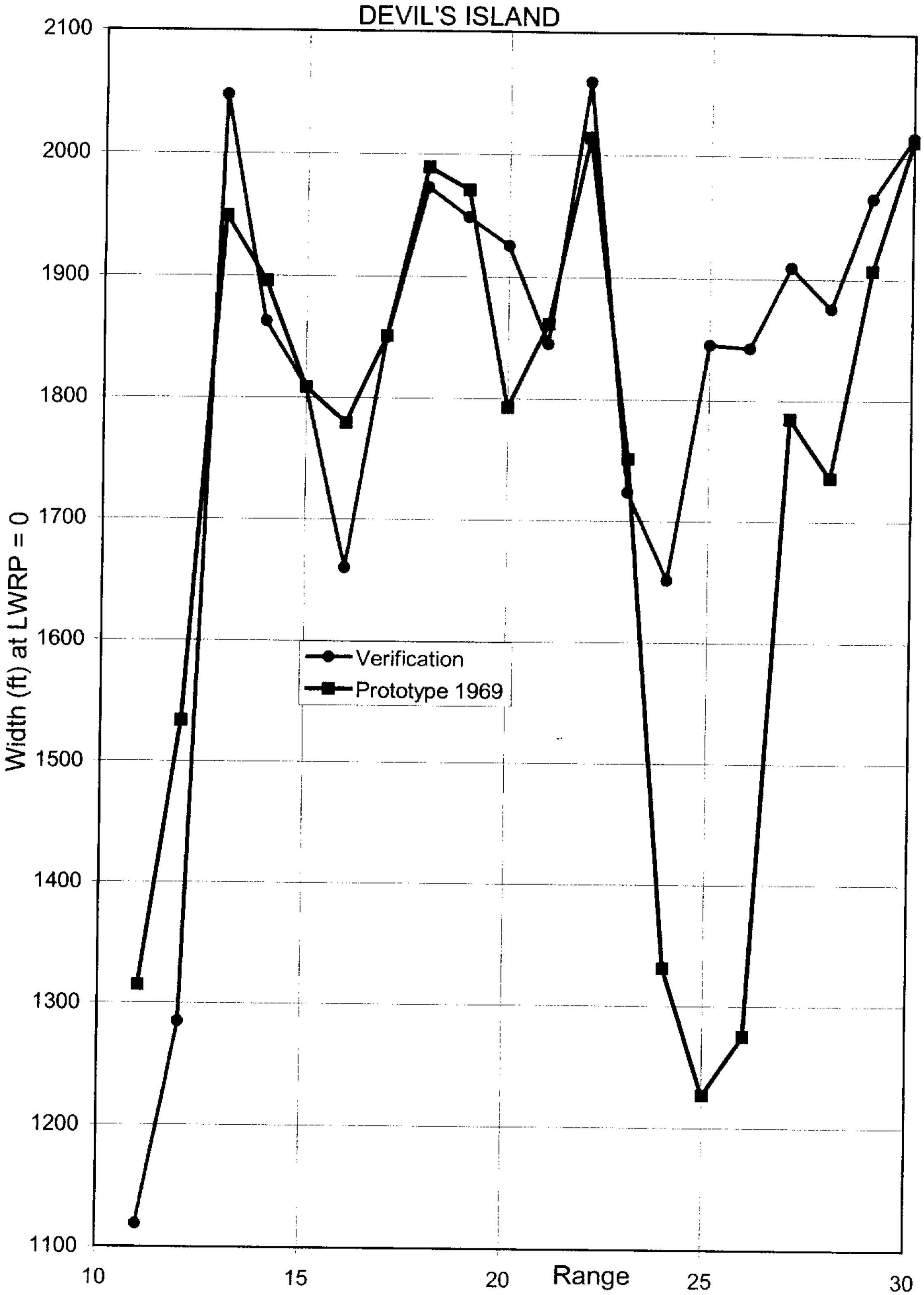

Figure B-5.2c Top Width by Range, Devil's Island

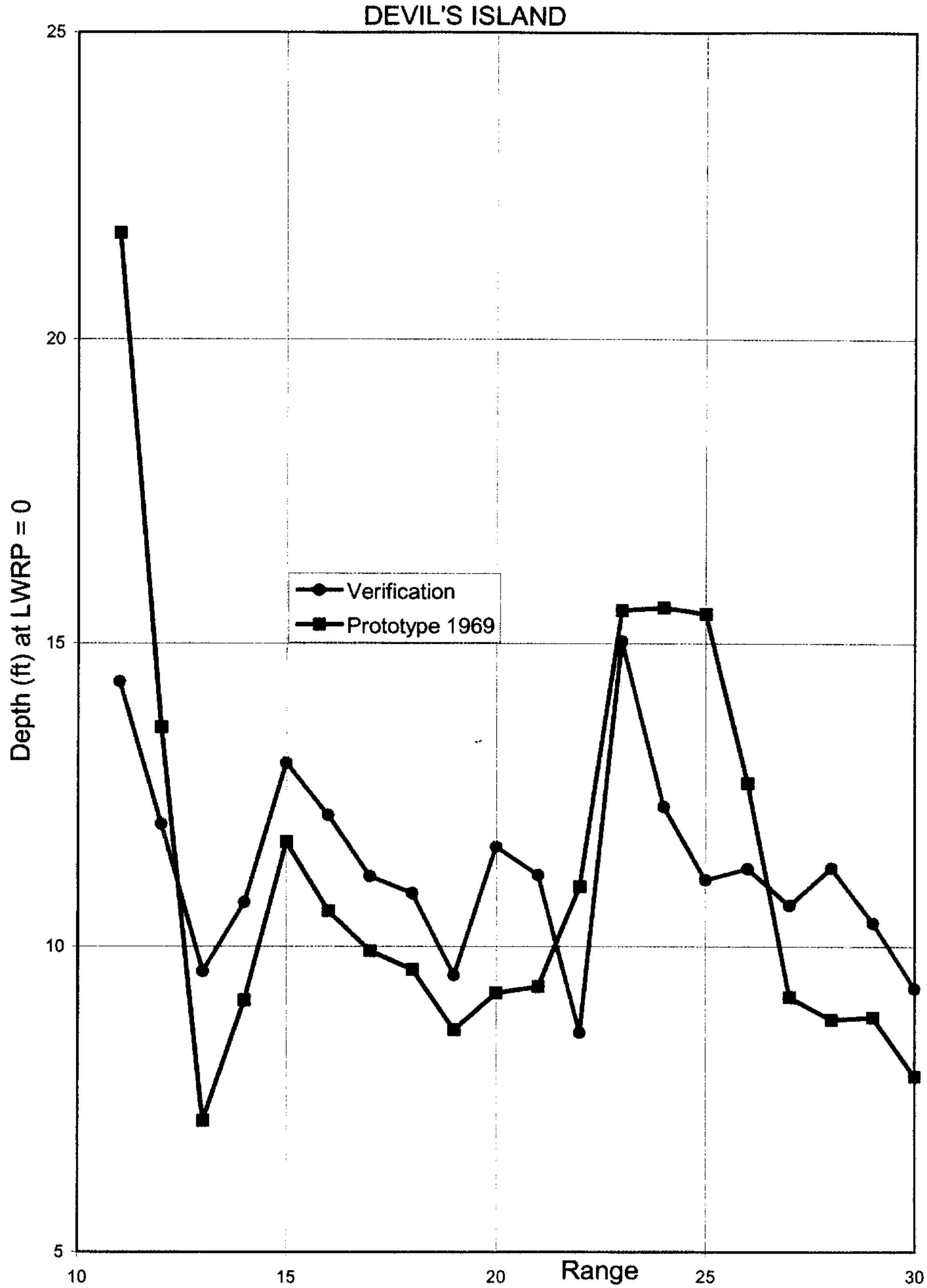

Figure B-5.2d Hydraulic Depth by Range, Devil's Island

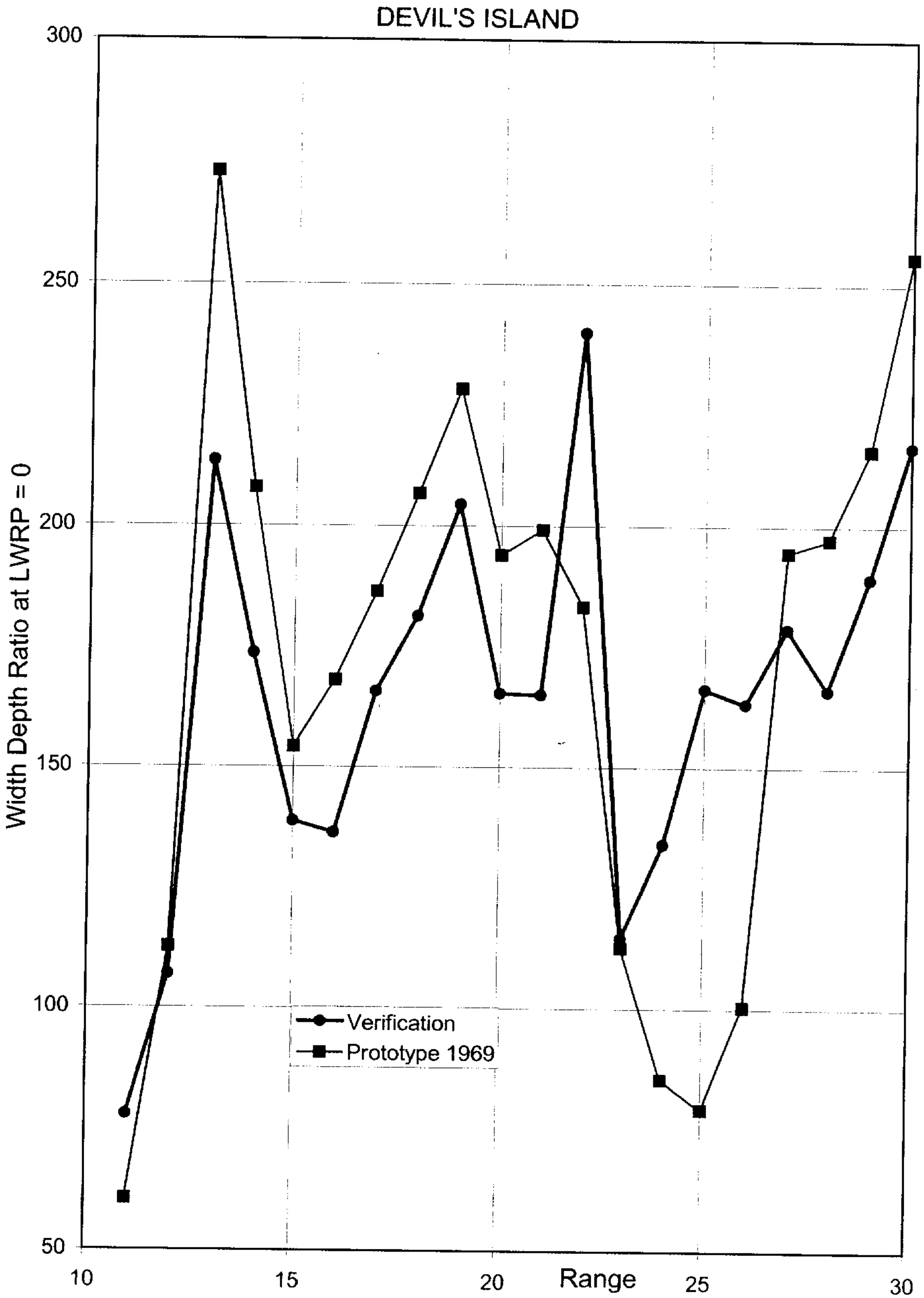

Figure B-5.2e Width/Depth Ratio by Range, Devil's Island

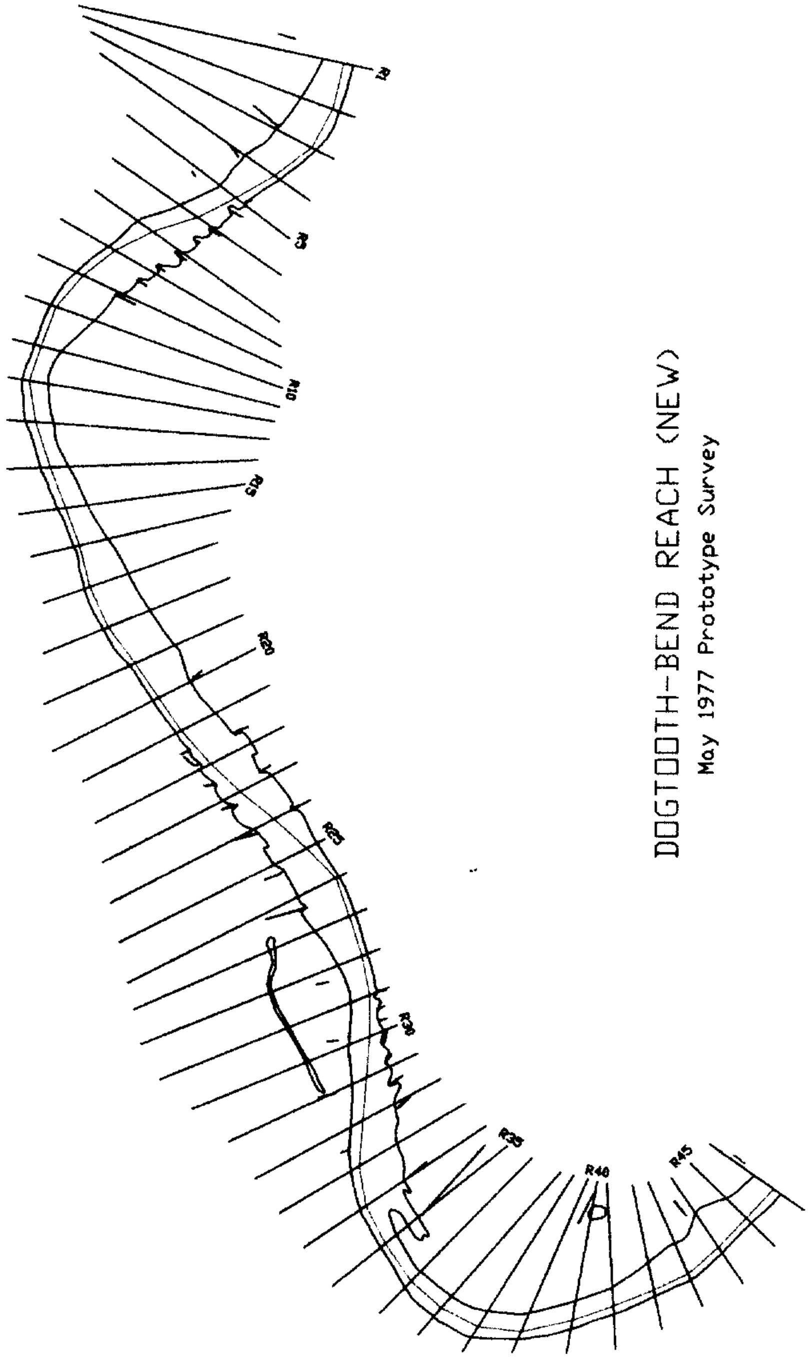

Figure B-6.1a Dogtooth Bend Model Plan View

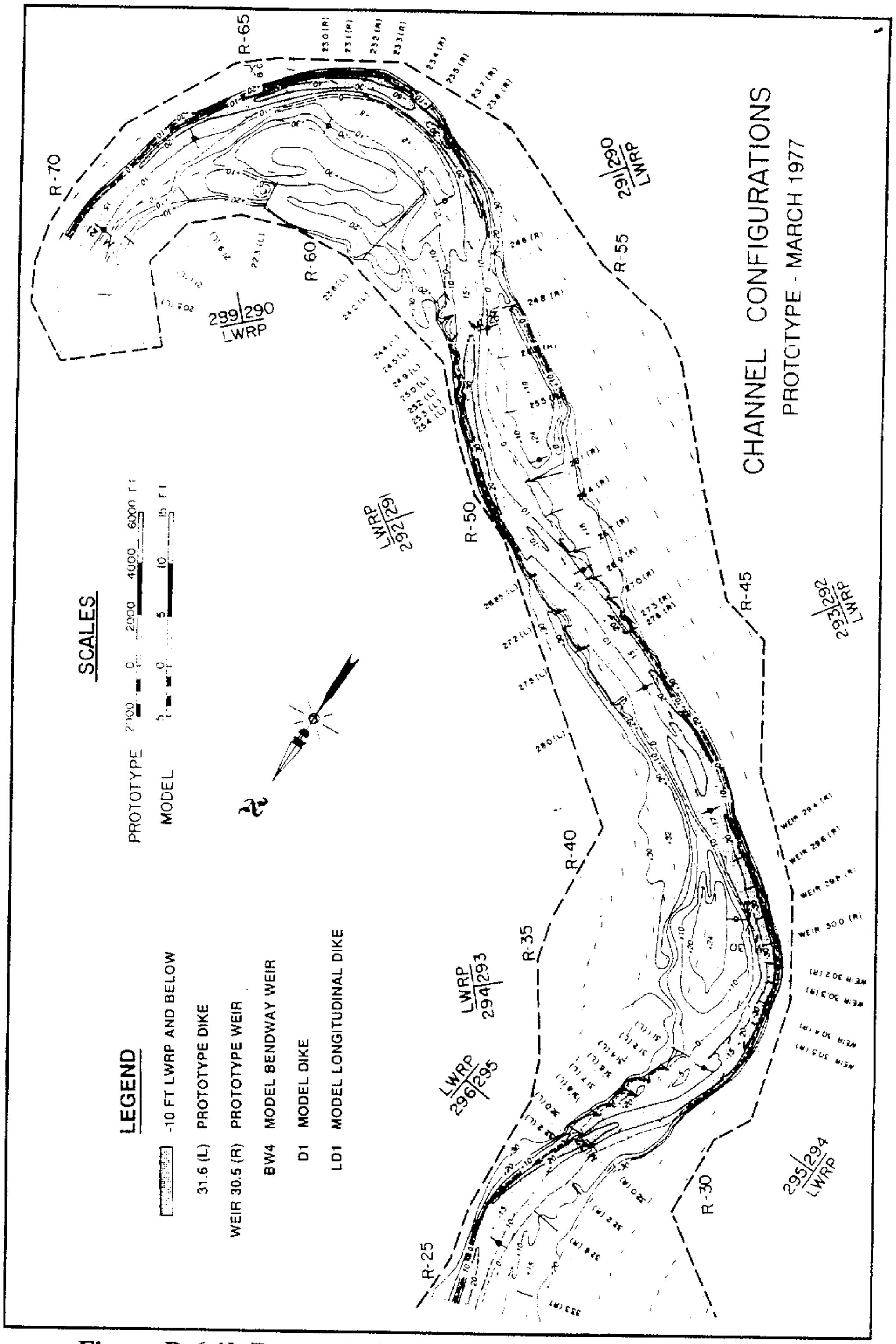

Figure B-6.1b Dogtooth Bend March 1977 Prototype Survey

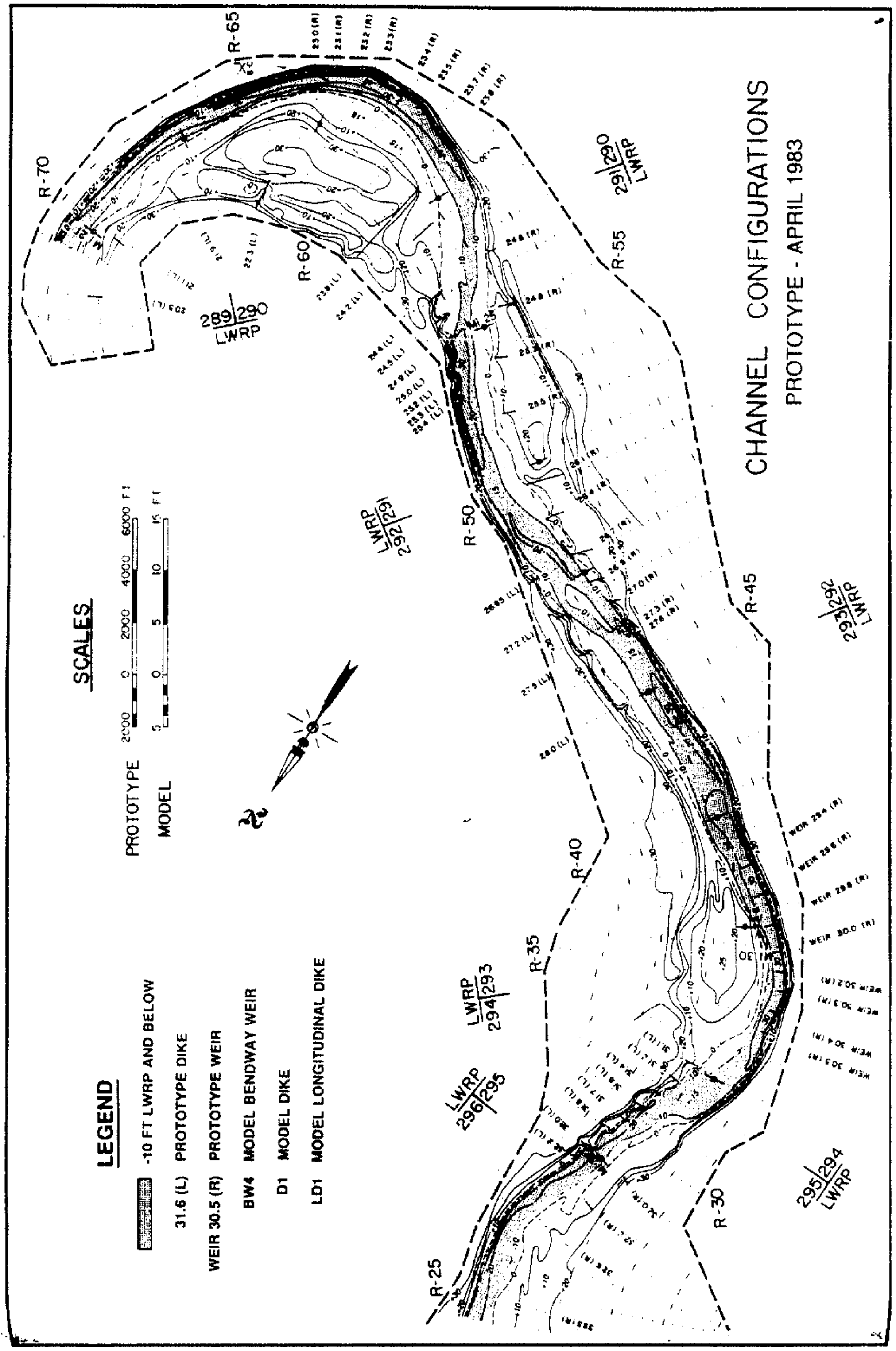

Figure B-6.1c Dogtooth Bend April 1983 Prototype Survey

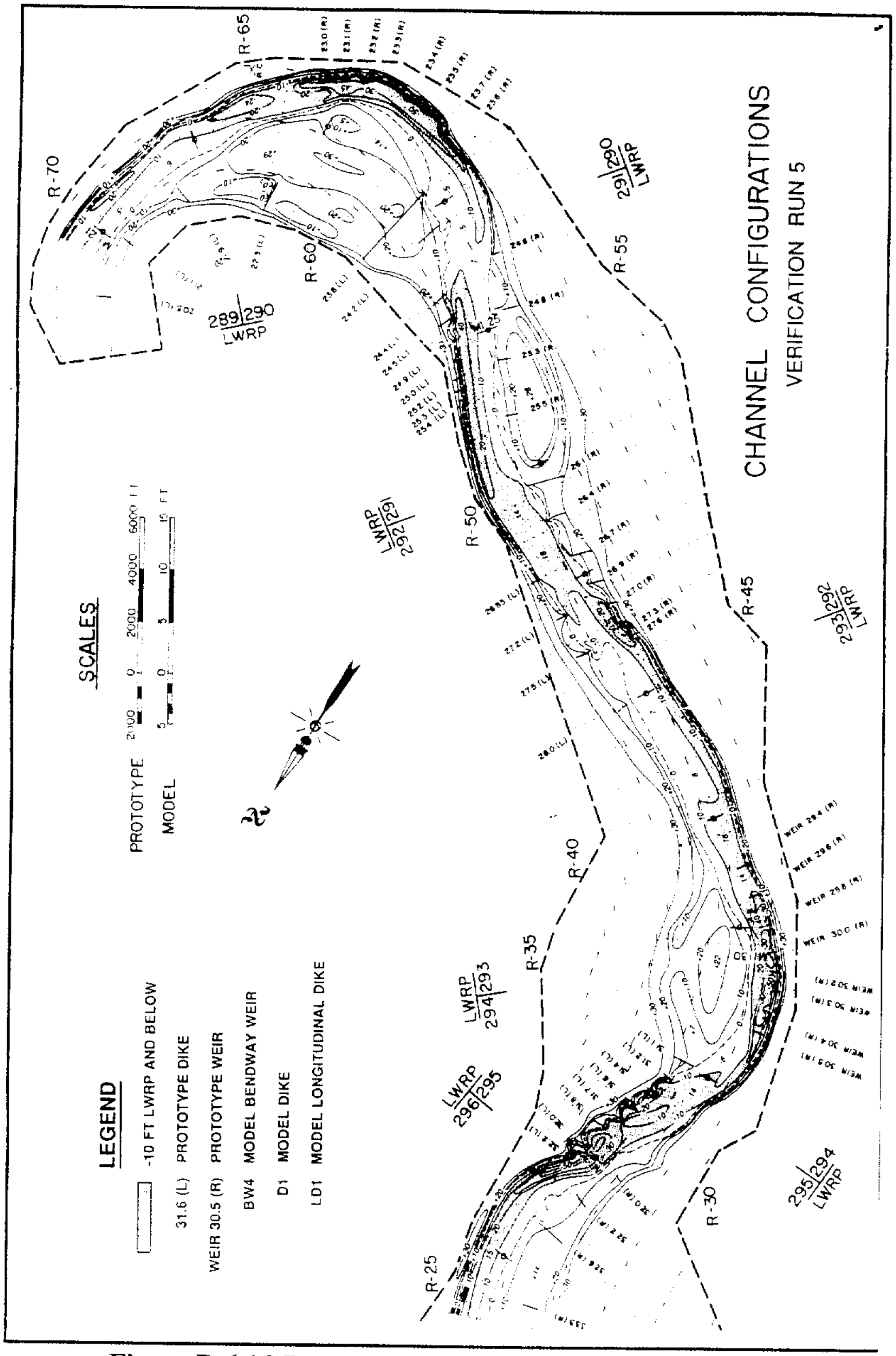

Figure B-6.1d Dogtooth Bend Verification Test Survey

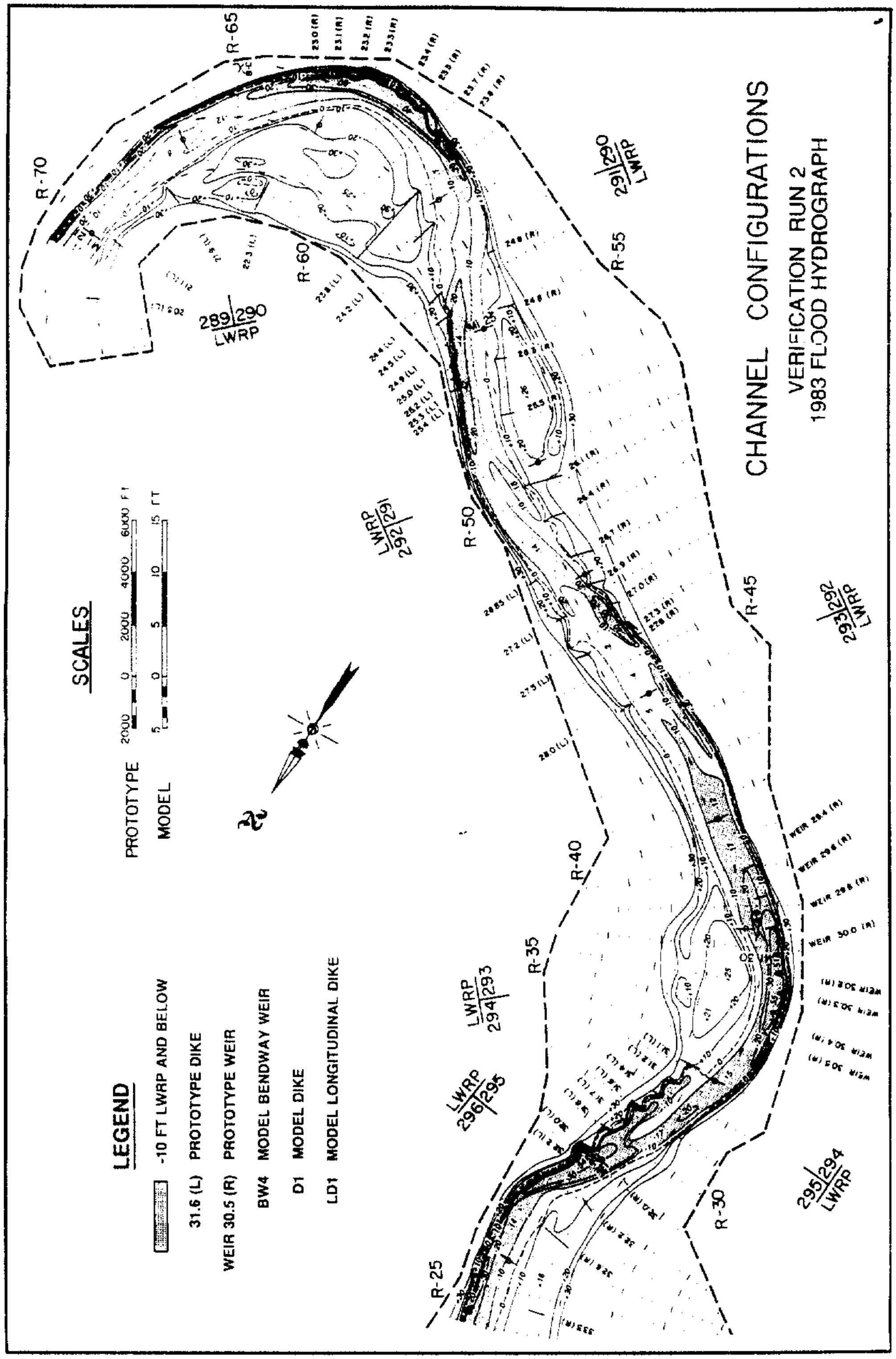

Figure B-6.1e Dogtooth Bend Verification Test Survey (with 1983 flood hydrograph)

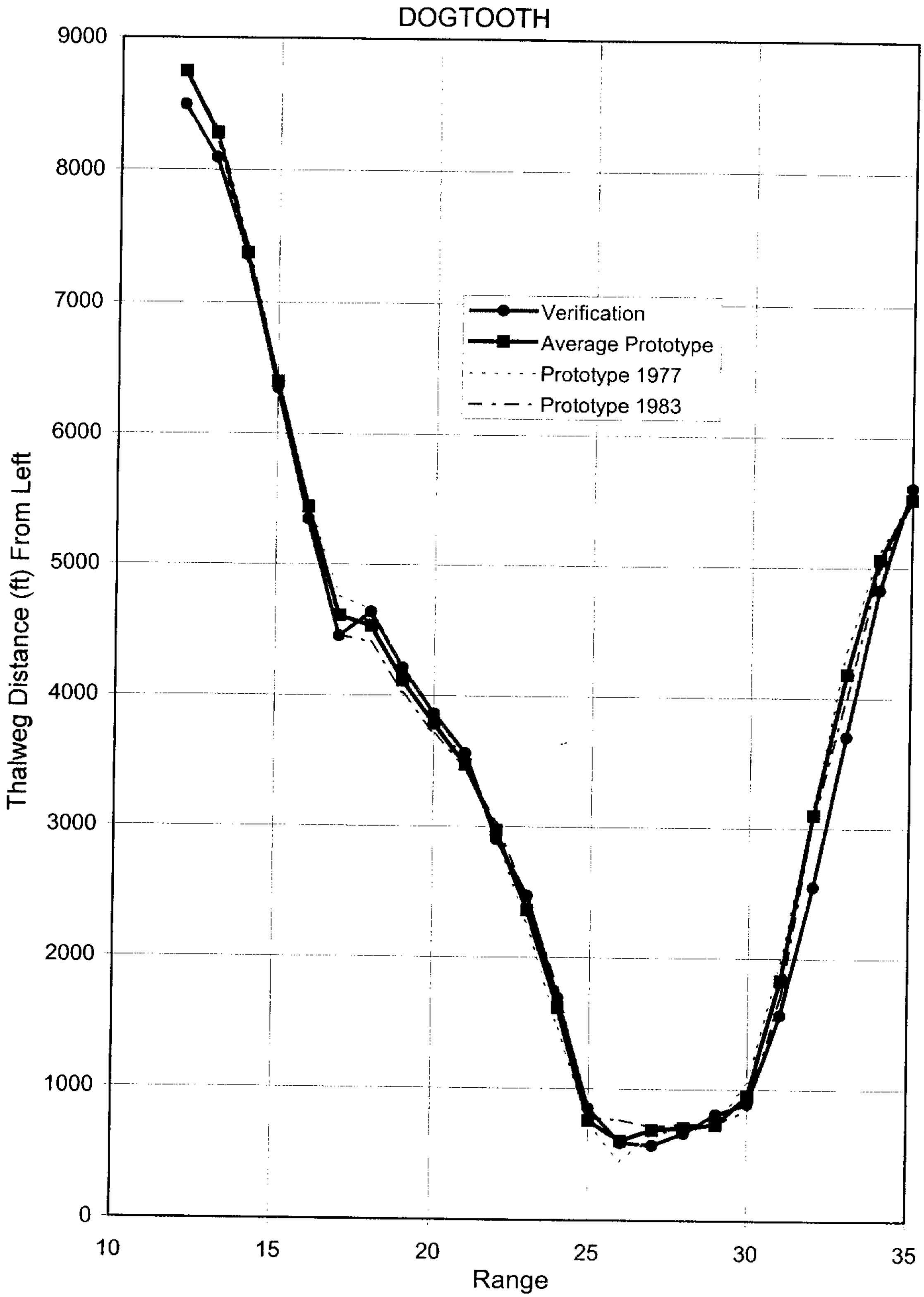

Figure B-6.2a Thalweg Position From Left by Range, Dogtooth

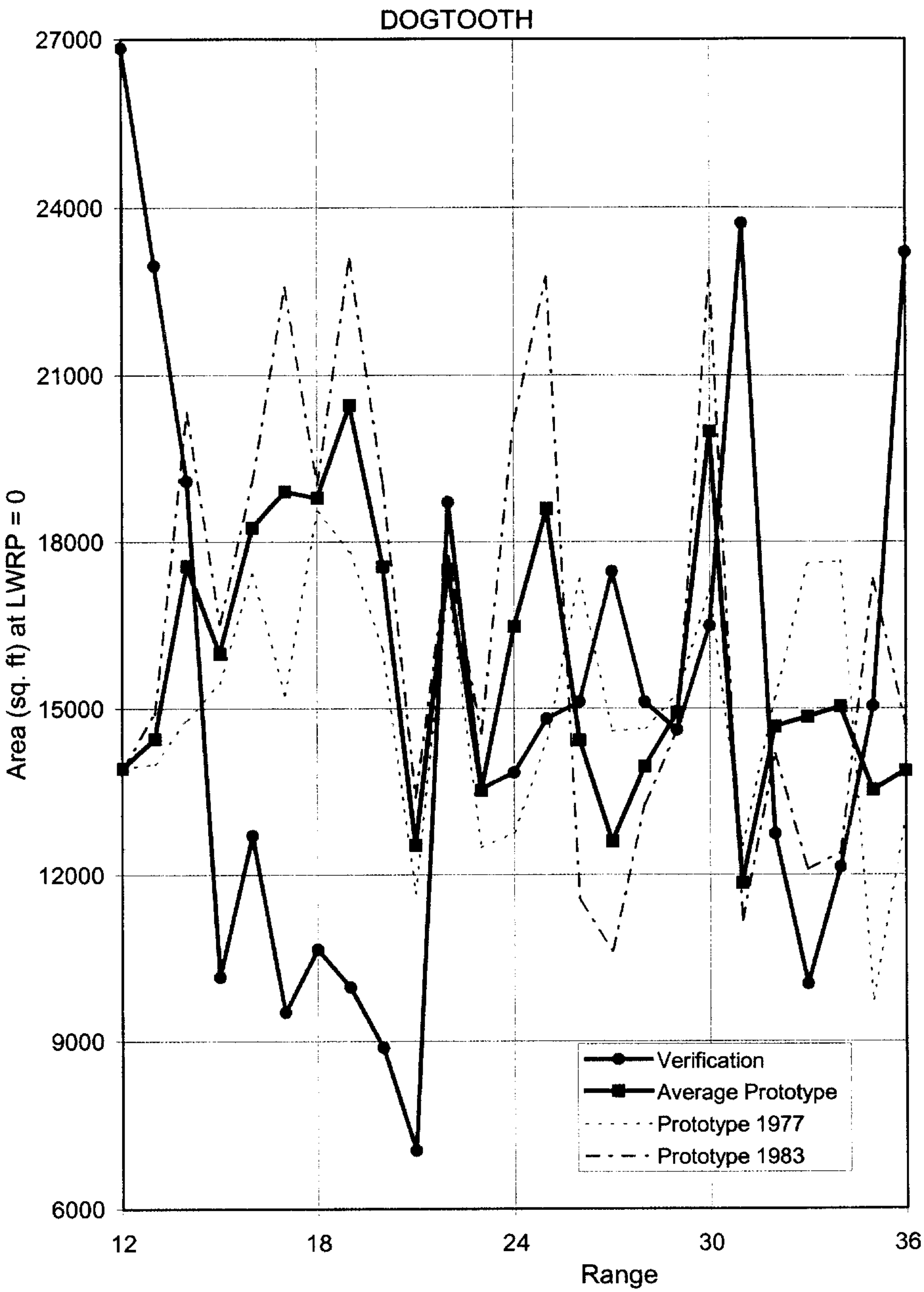

Figure B-6.2b Cross-Section Area by Range, Dogtooth

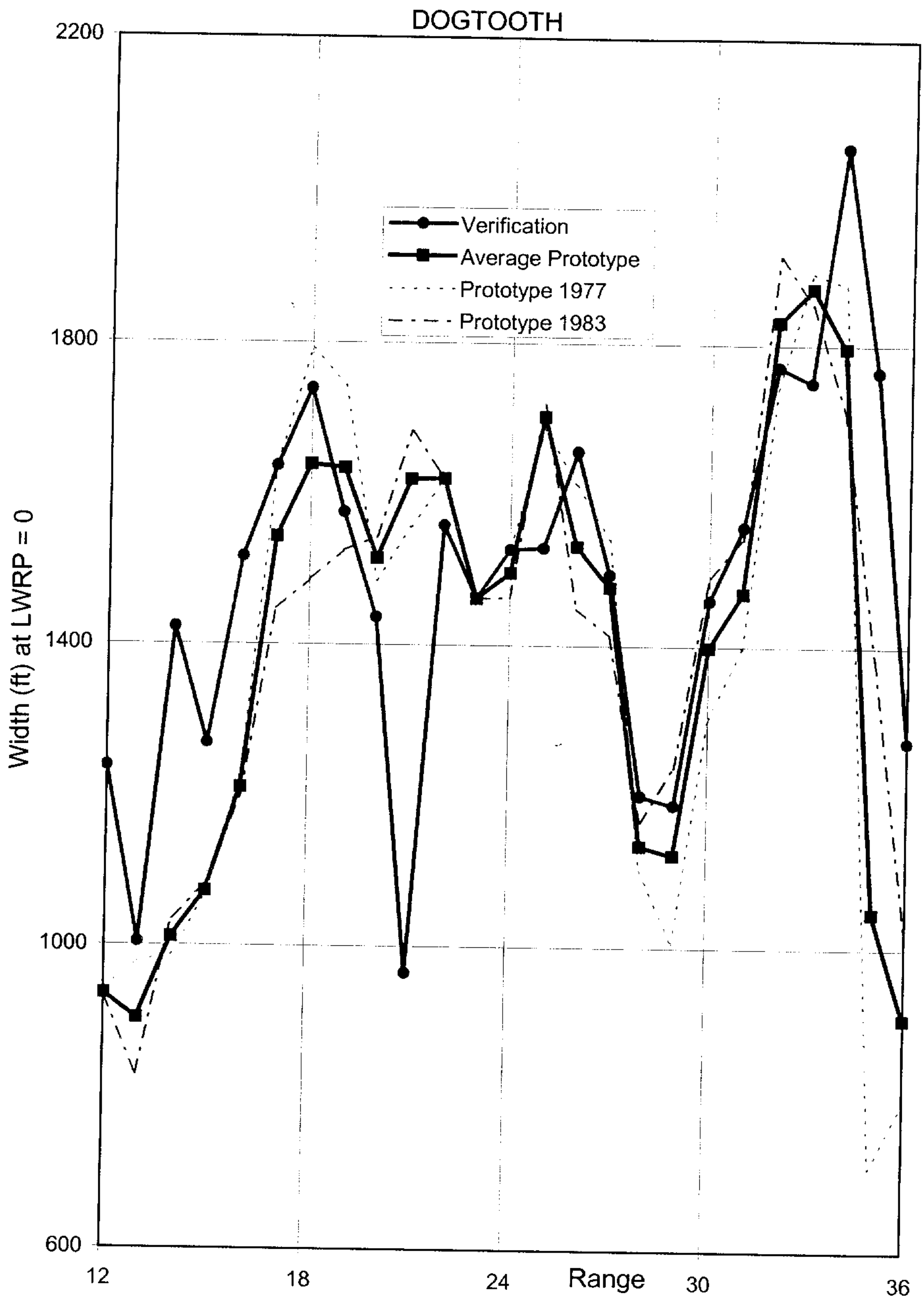

Figure B-6.2c Top Width Area by Range, Dogtooth

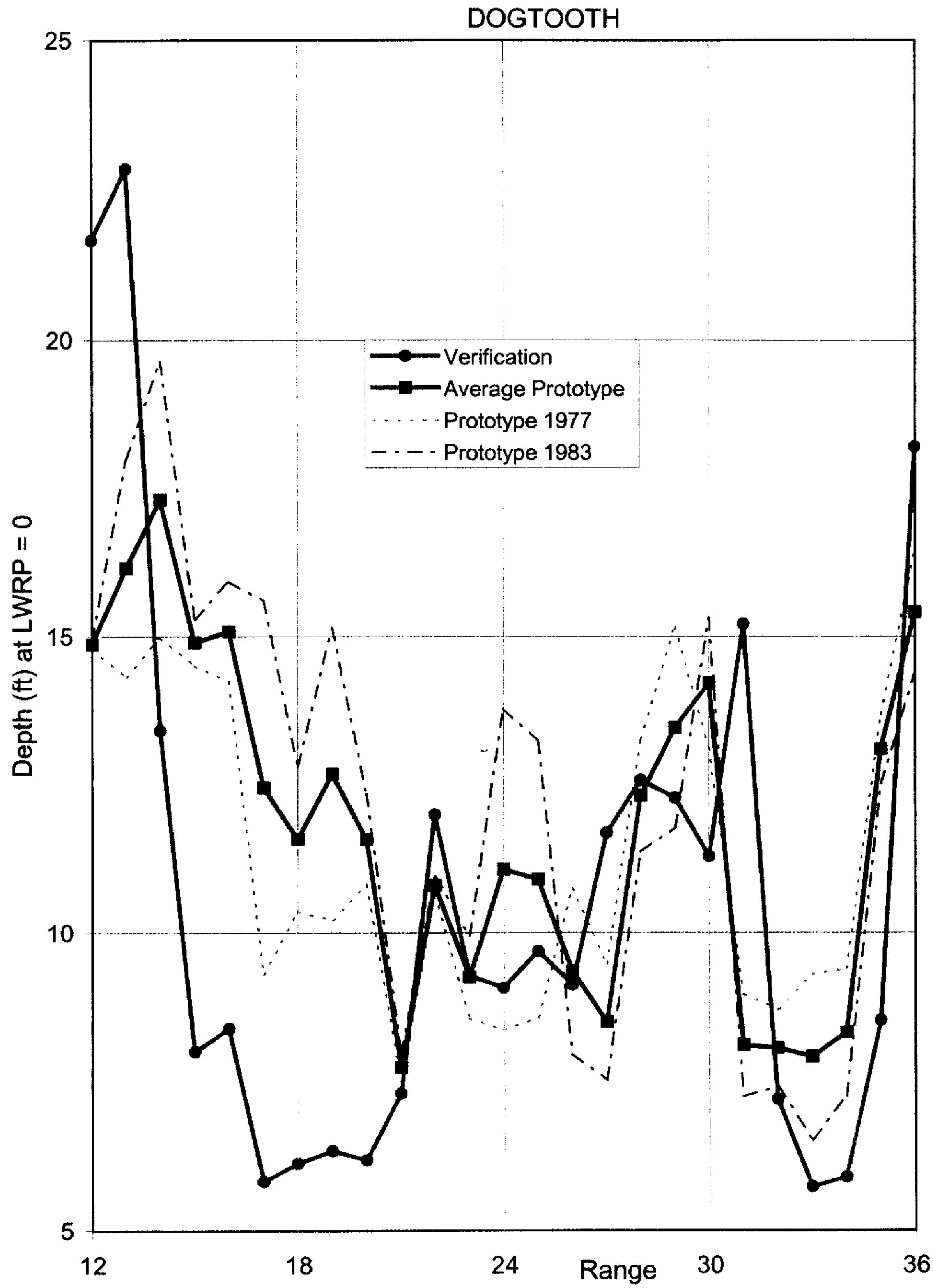

Figure B-6.2d Hydraulic Depth by Range, Dogtooth

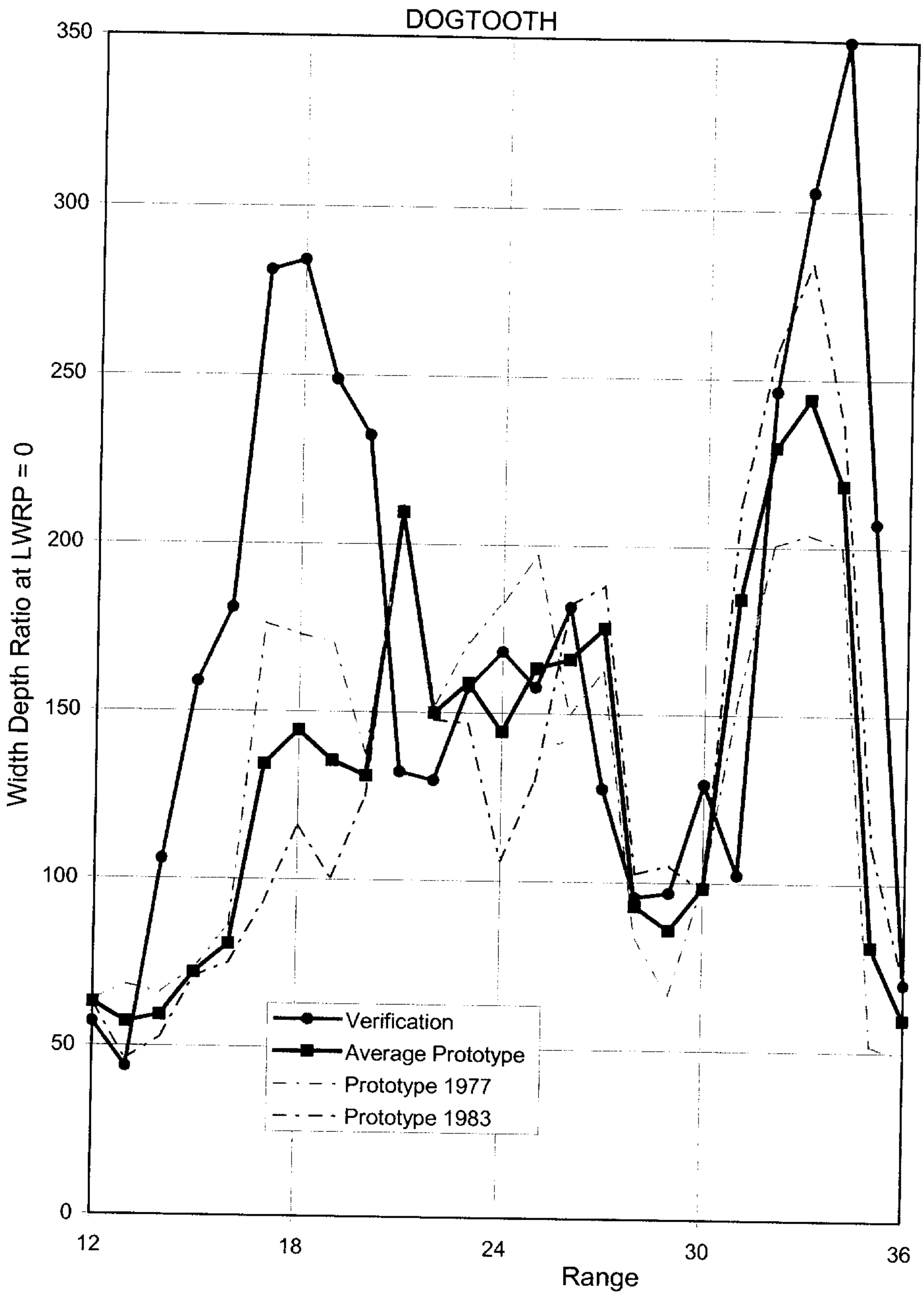

Figure B-6.2e Width/Depth Ratio by Range, Dogtooth

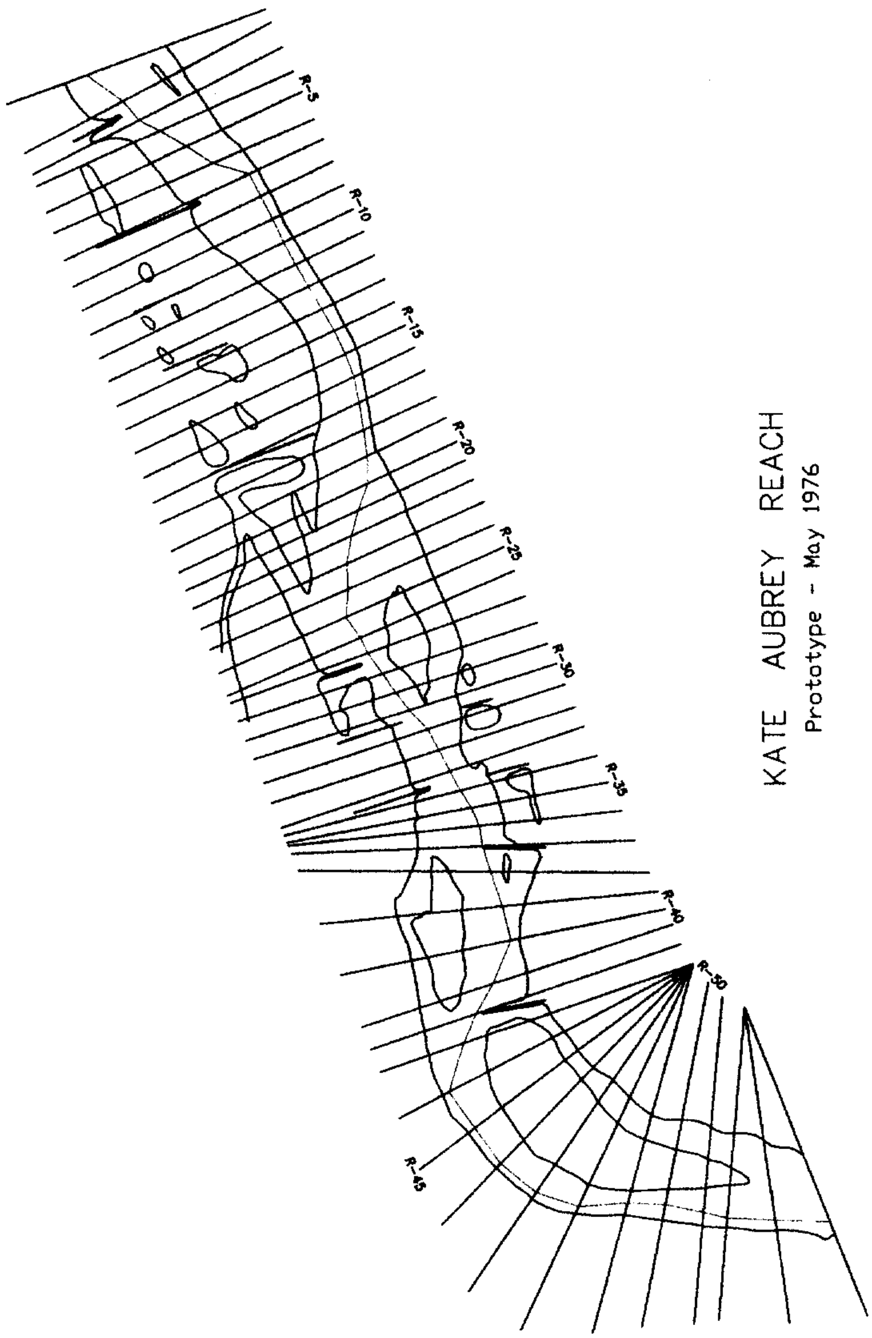

Figure B-7.1a Kate Aubrey Model Plan View

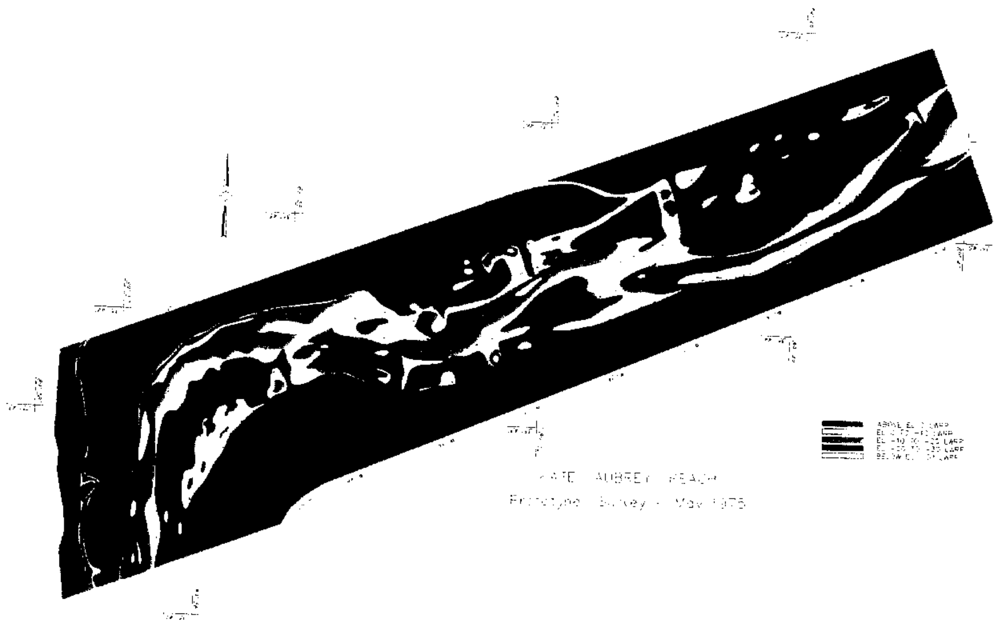

Figure B-7.1b Kate Aubrey May 1975 Prototype Survey

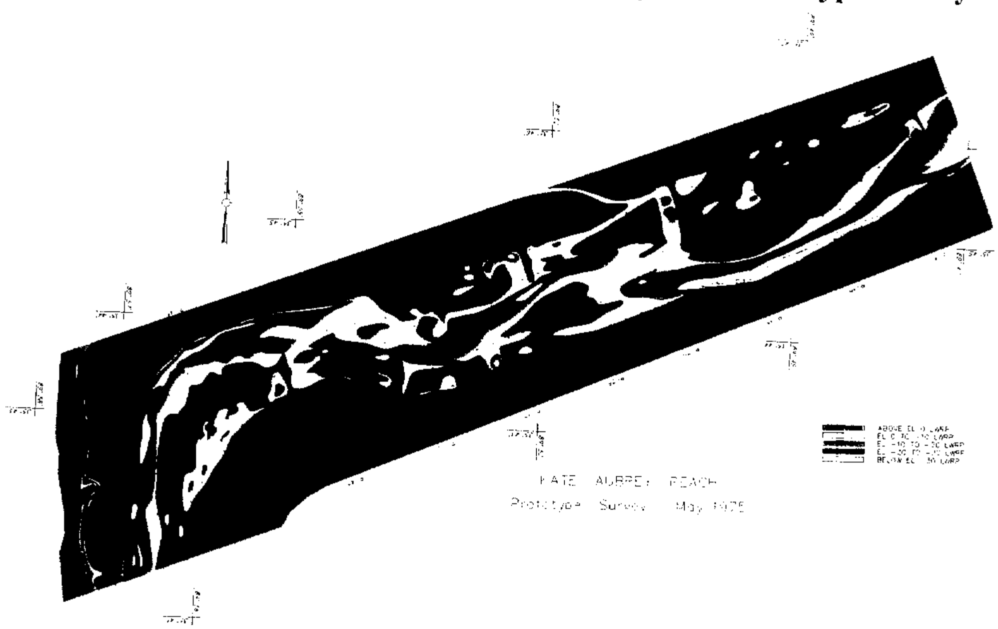

Figure B-7.1c Kate Aubrey May 1976 Prototype Survey

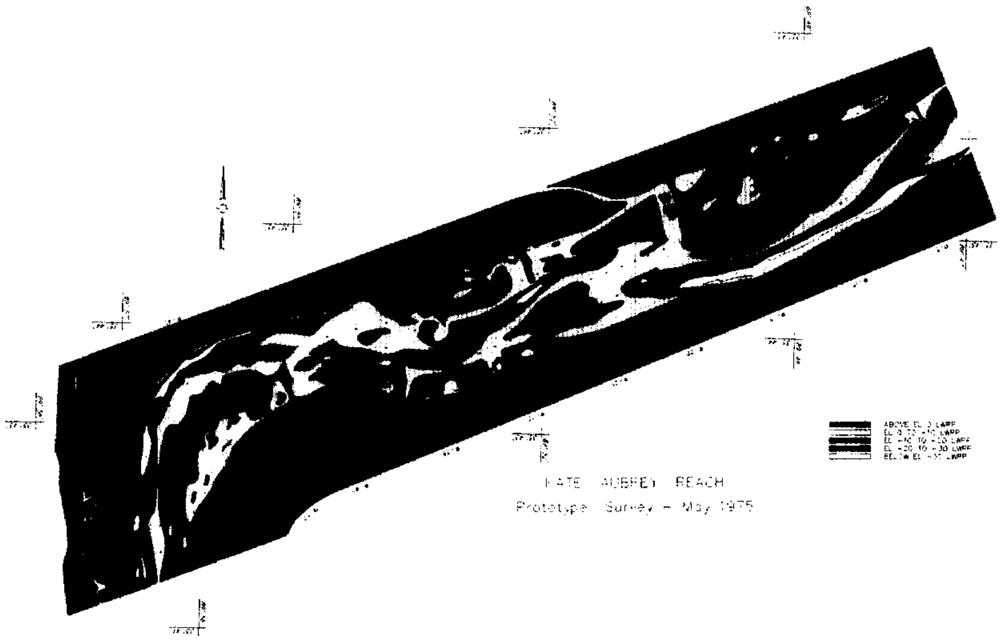

Figure B-7.1d Kate Aubrey Verification Test Survey

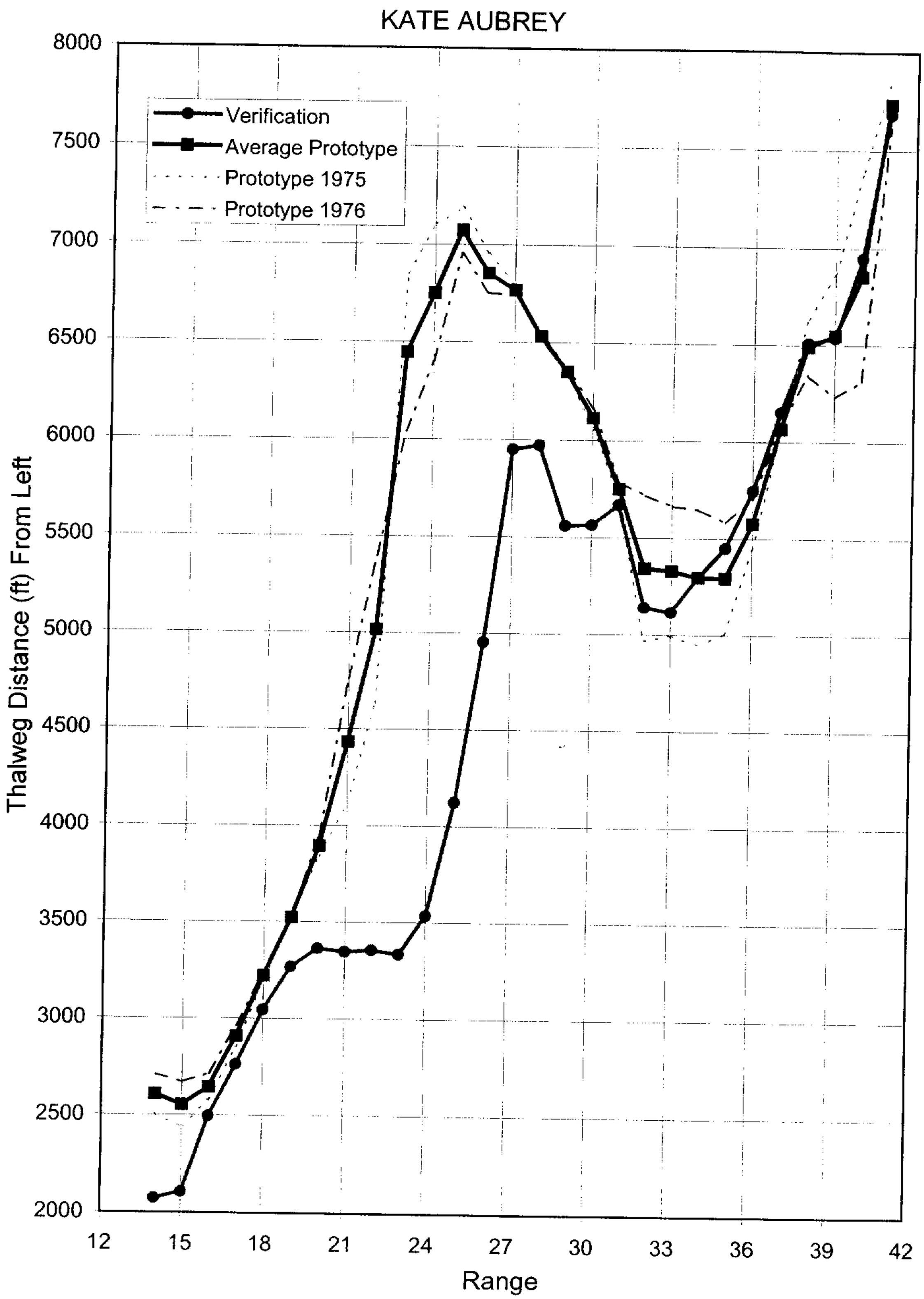

Figure B-7.2a Thalweg Position From Left by Range, Kate Aubrey

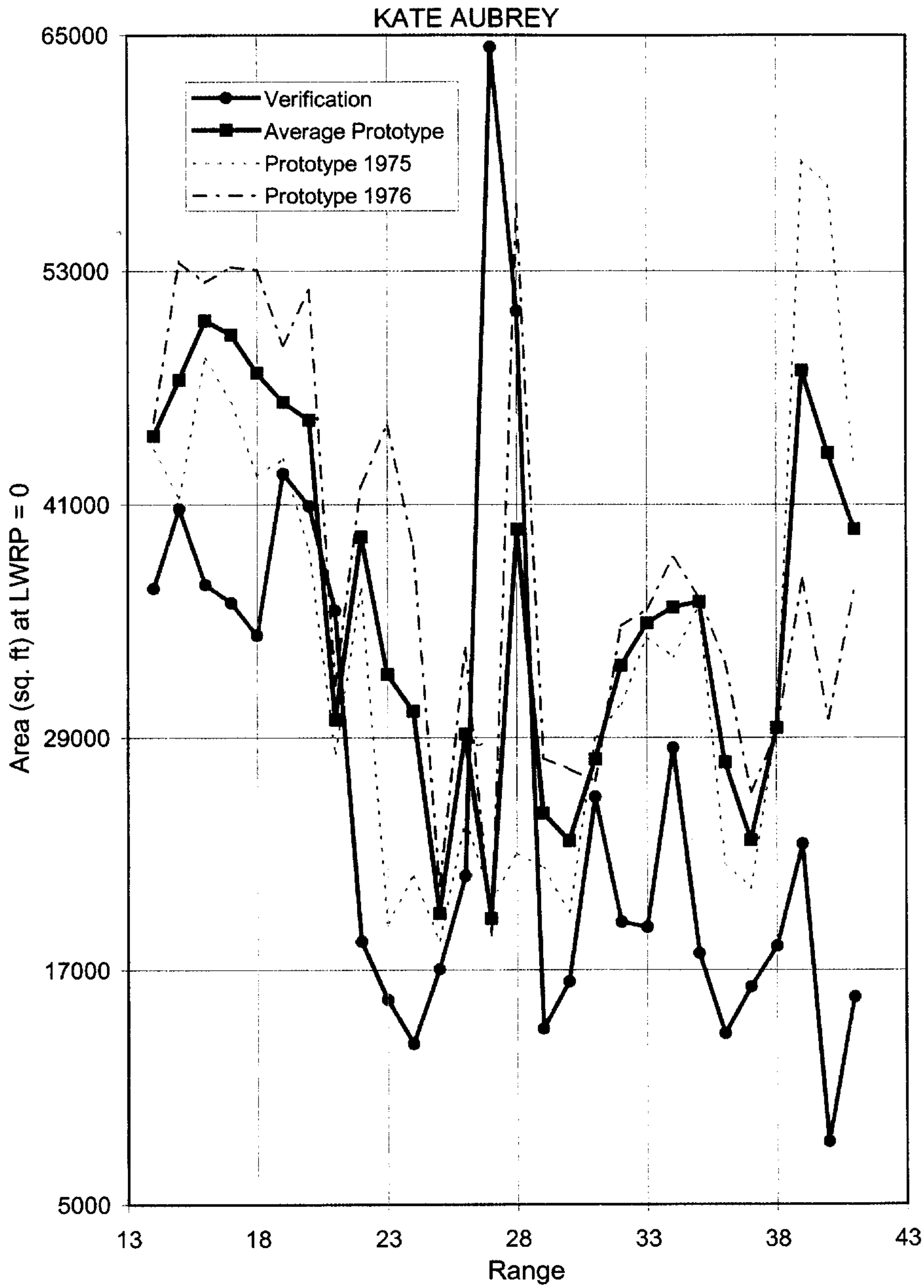

Figure B-7.2b Cross-Section Area by Range, Kate Aubrey

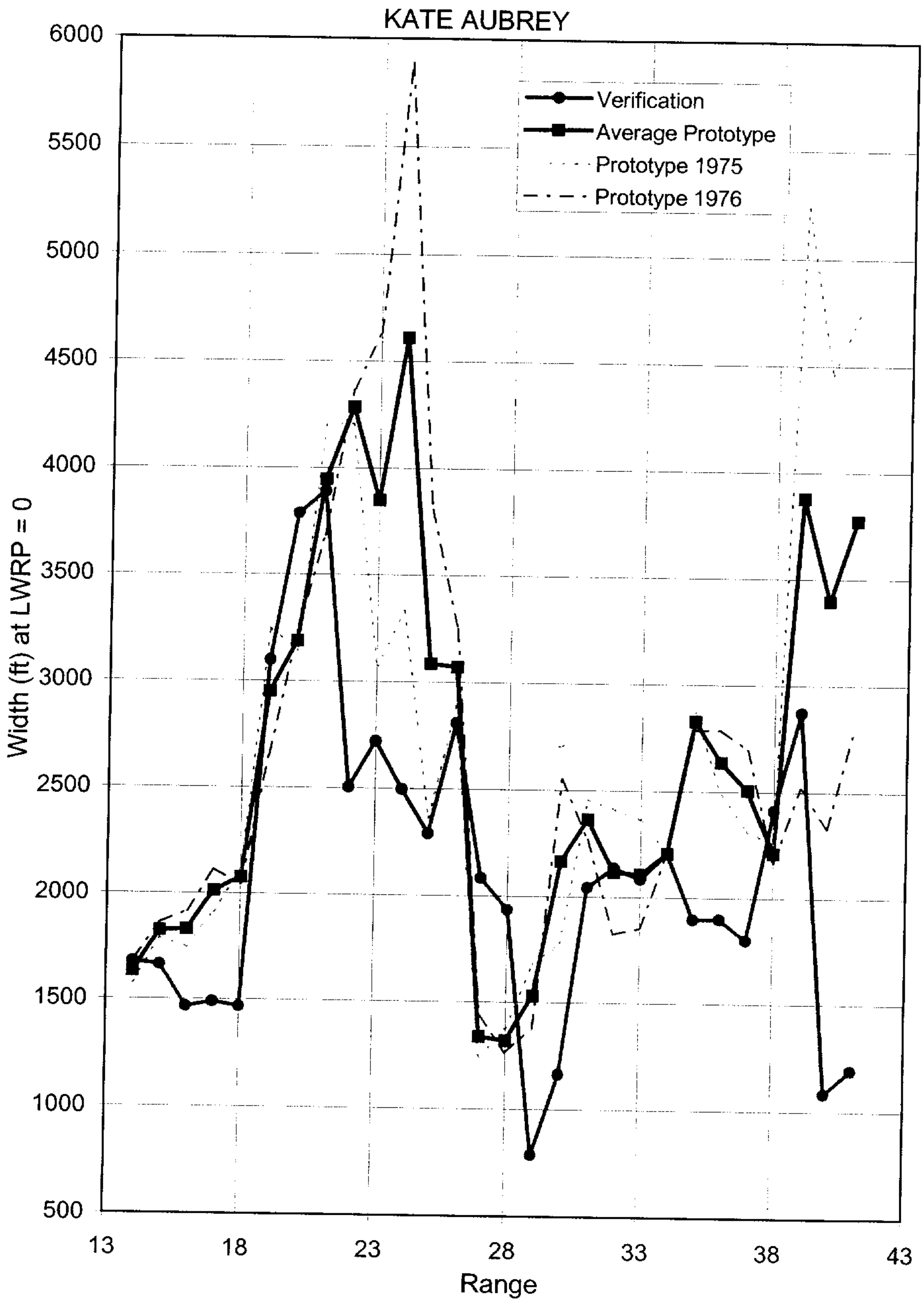

Figure B-7.2c Top Width by Range, Kate Aubrey

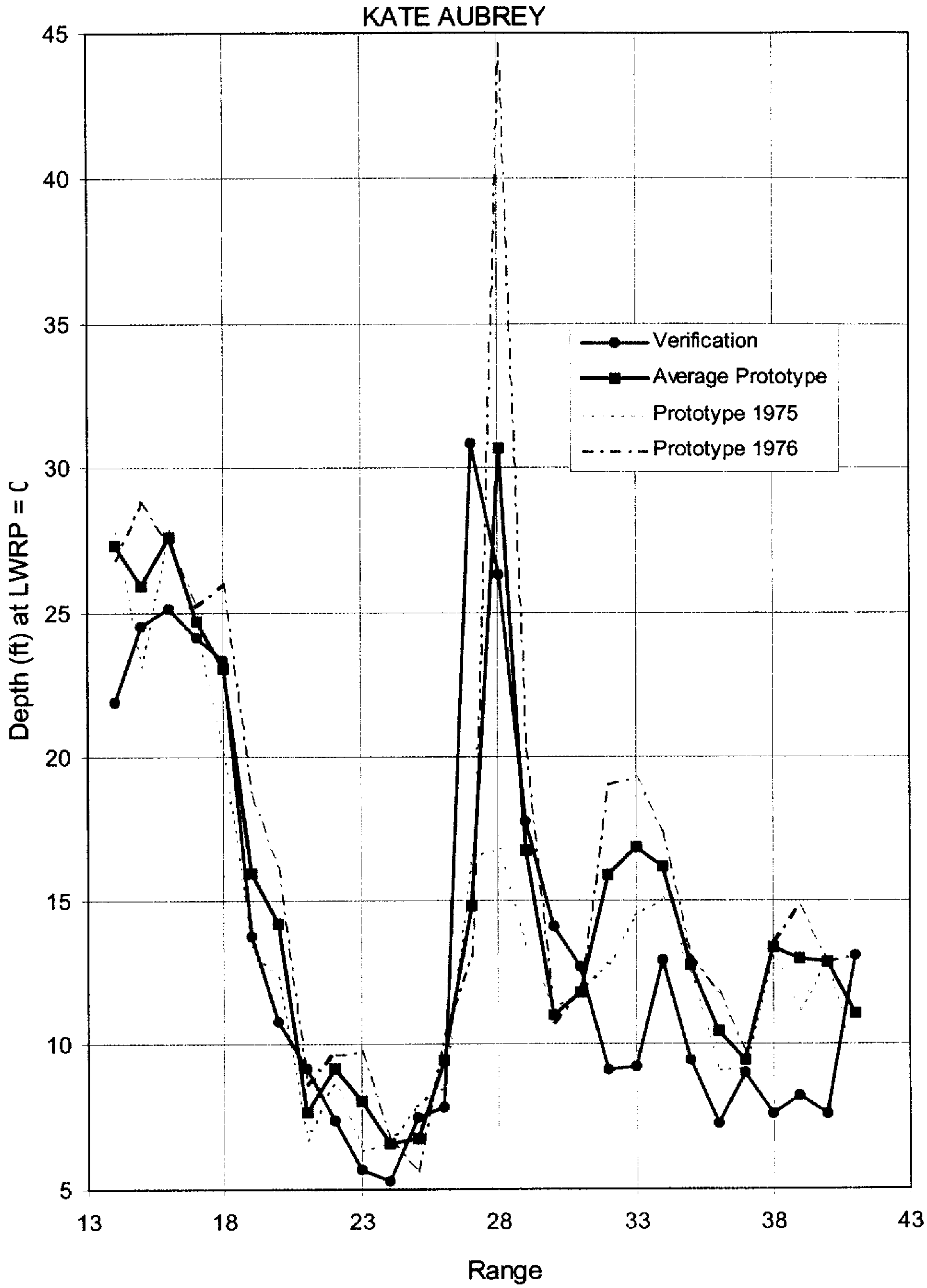

Figure B-7.2d Hydraulic Depth by Range, Kate Aubrey

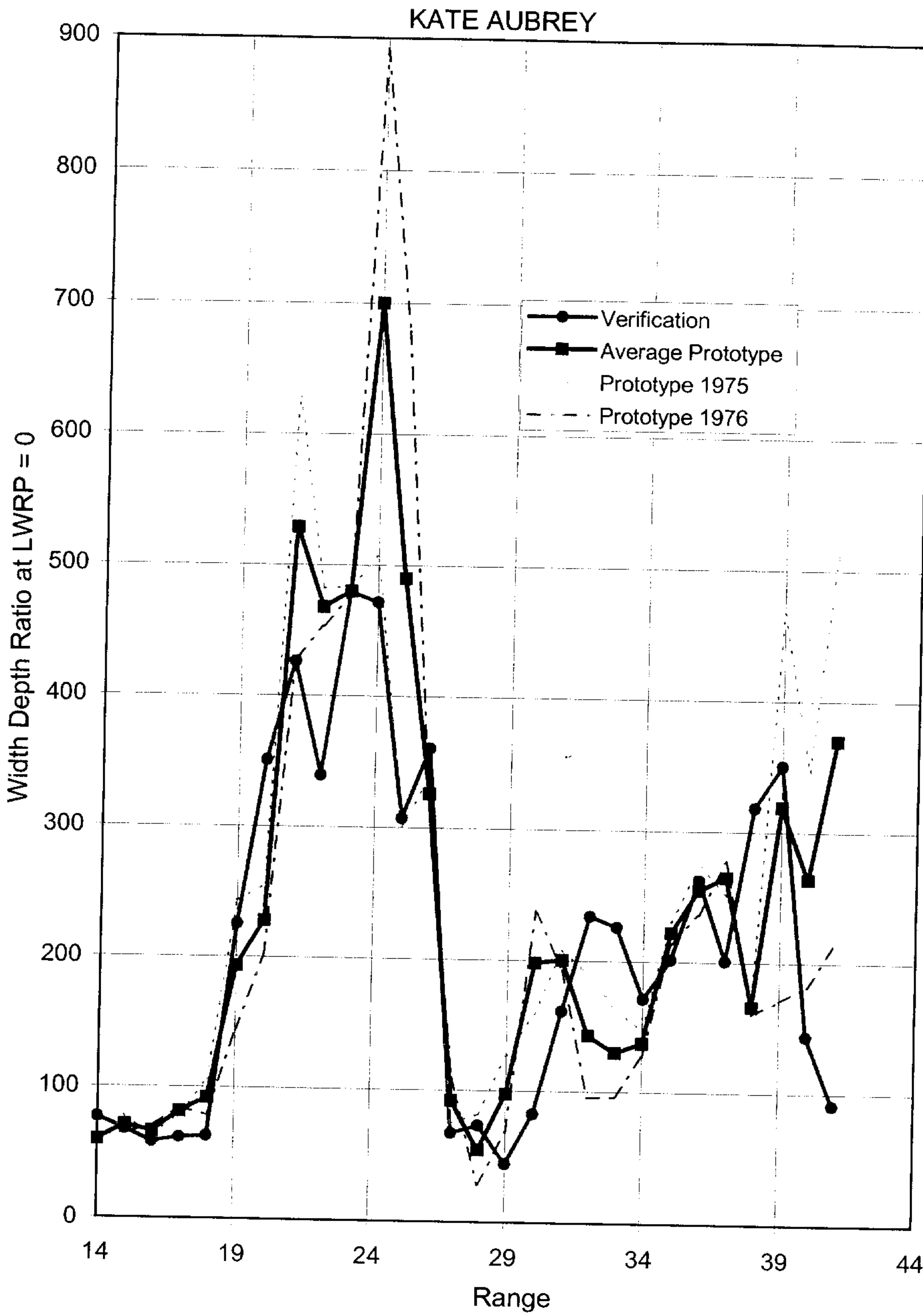

Figure B-7.2e Width/Depth Ratio by Range, Kate Aubrey

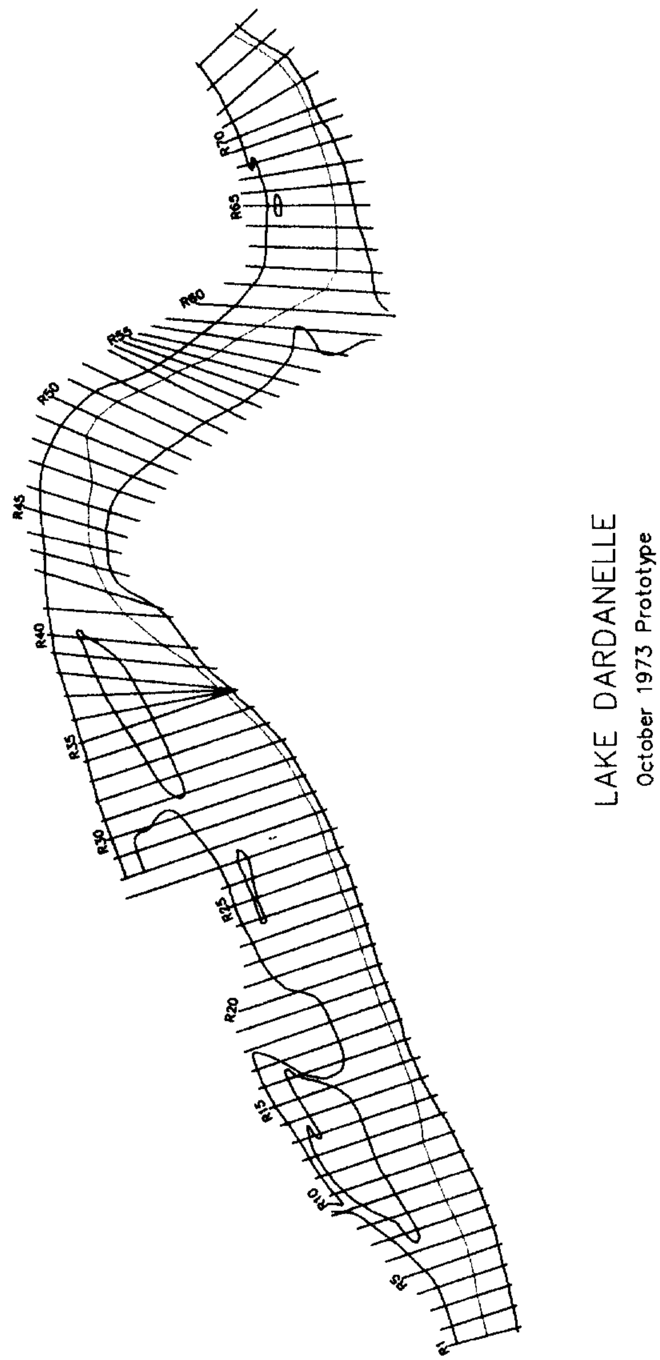

Figure B-8.1a Lake Dardanelle Model Plan View

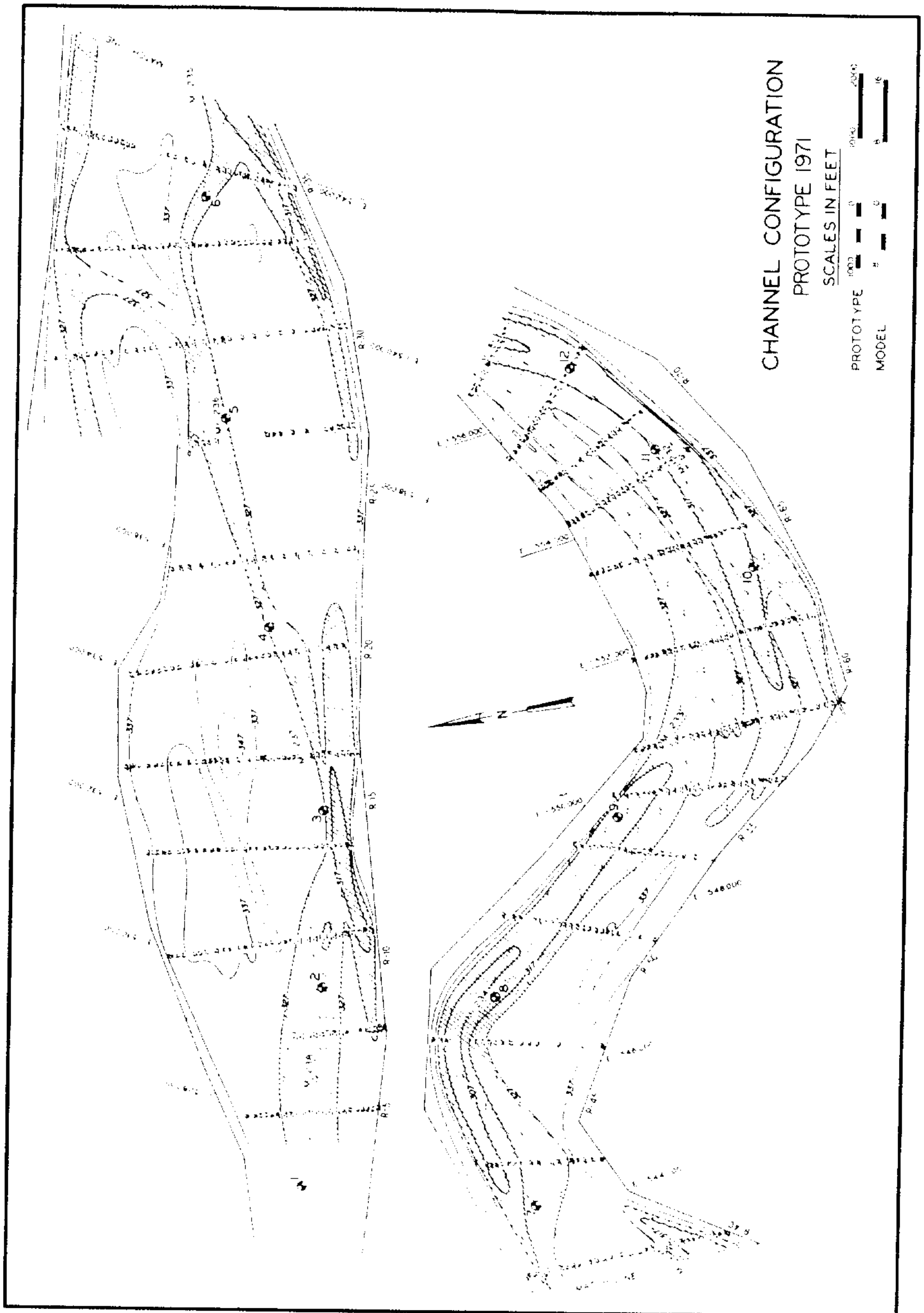

Figure B-8.1b Lake Dardanelle November 1971 Prototype Survey

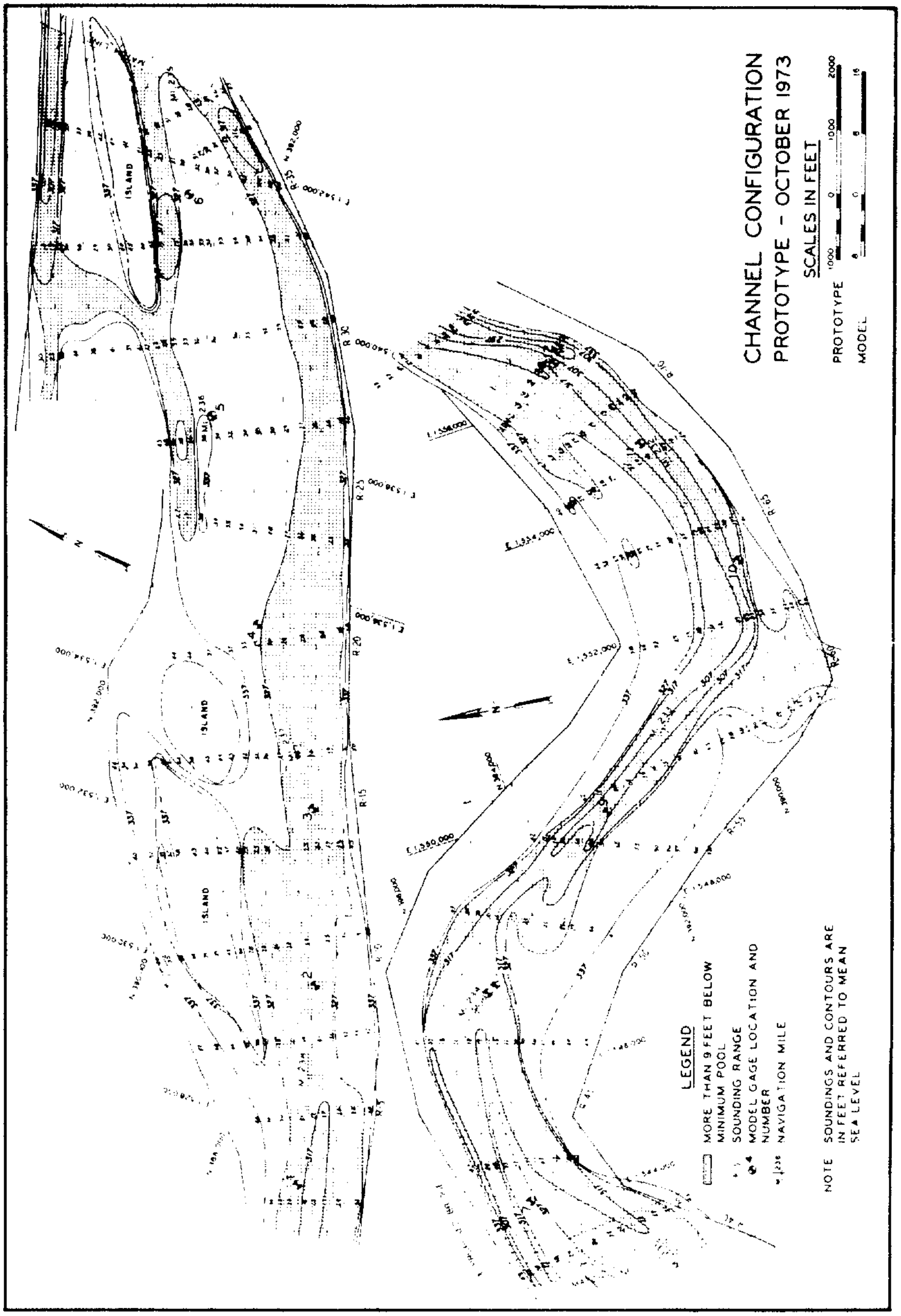

Figure B-8.1c Lake Dardanelle October 1973 Prototype Survey

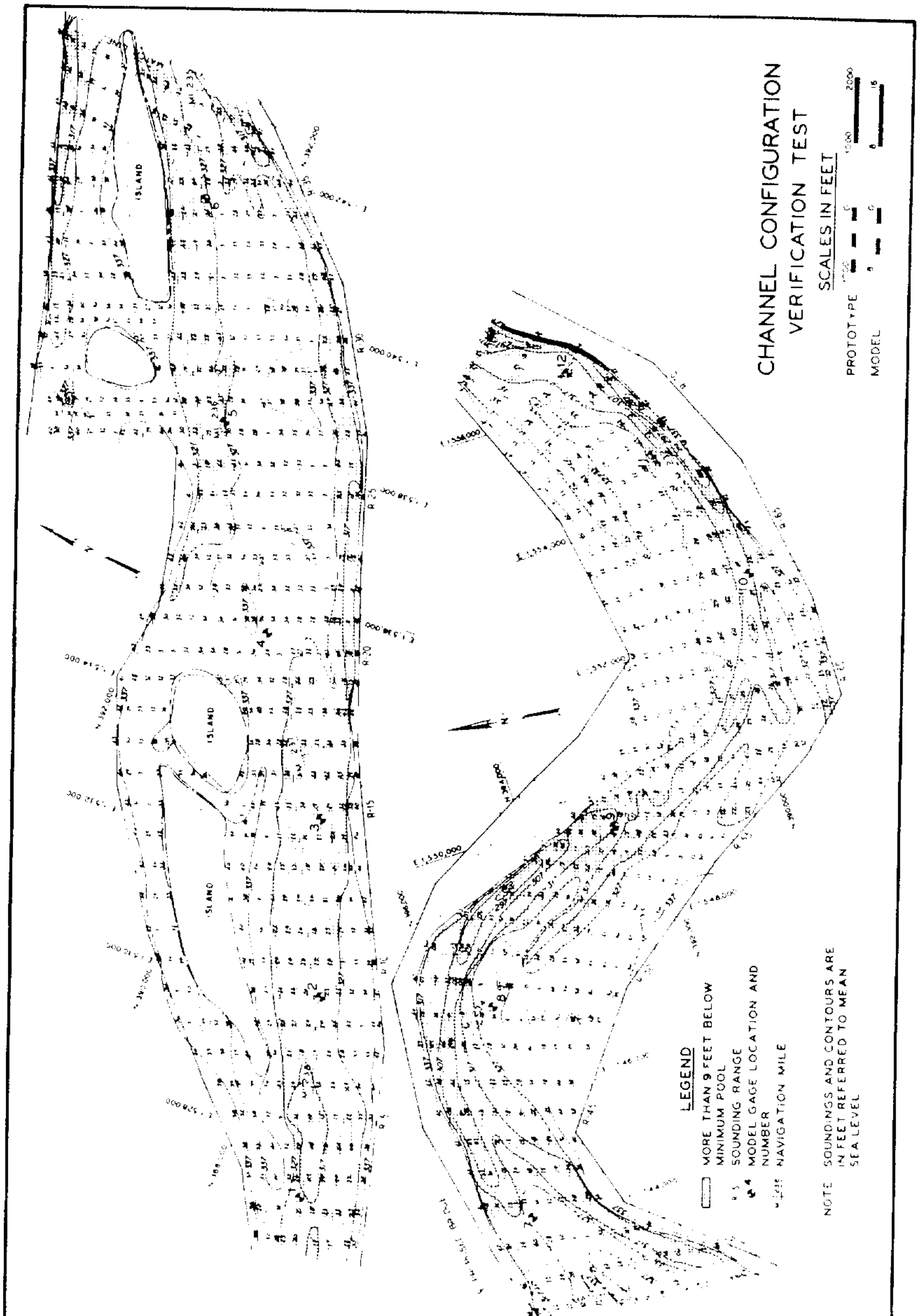

Figure B-8.1d Lake Dardanelle Verification Test Survey

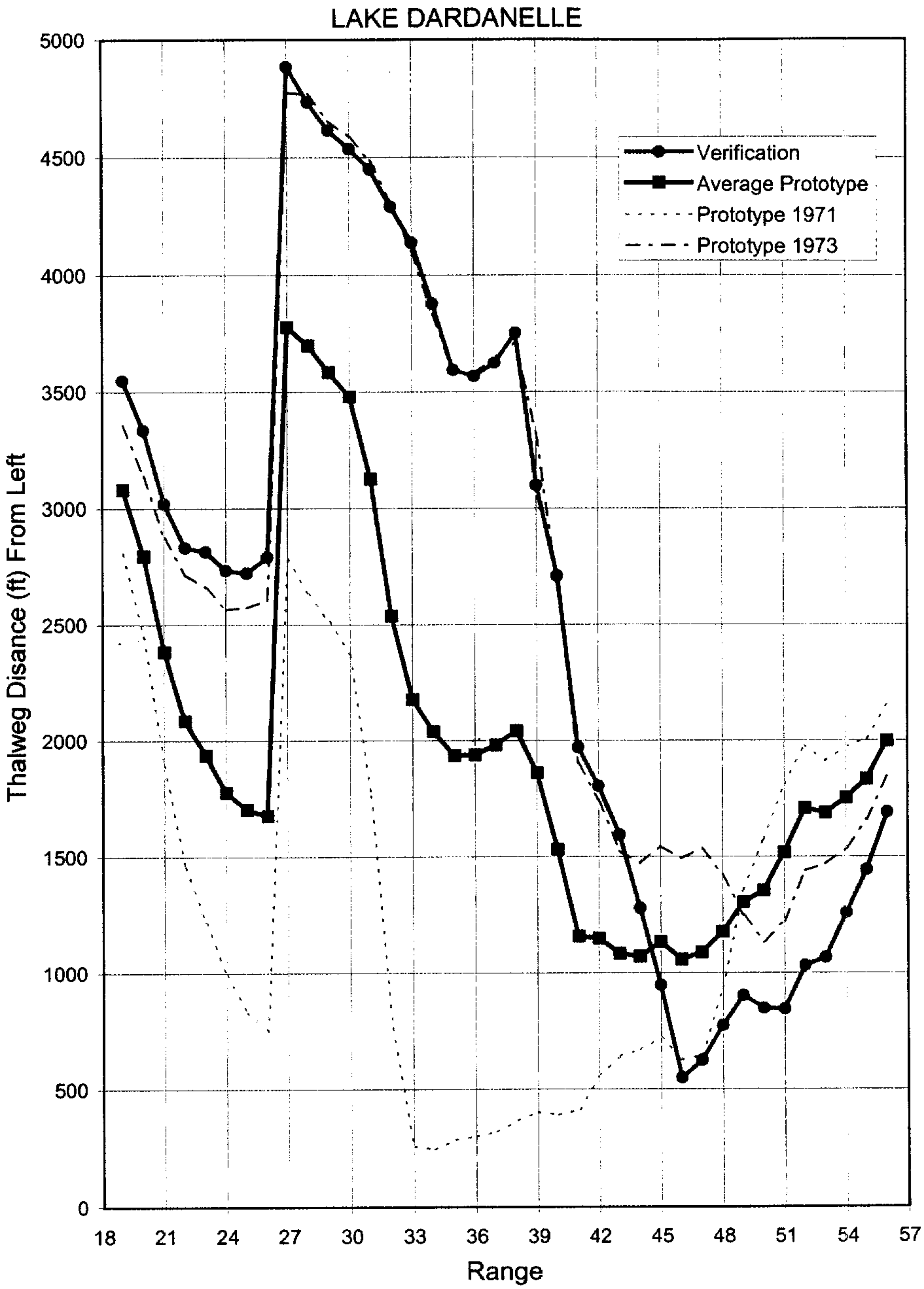

Figure B-8.2a Thalweg Position From Left by Range, Lake Dardanelle

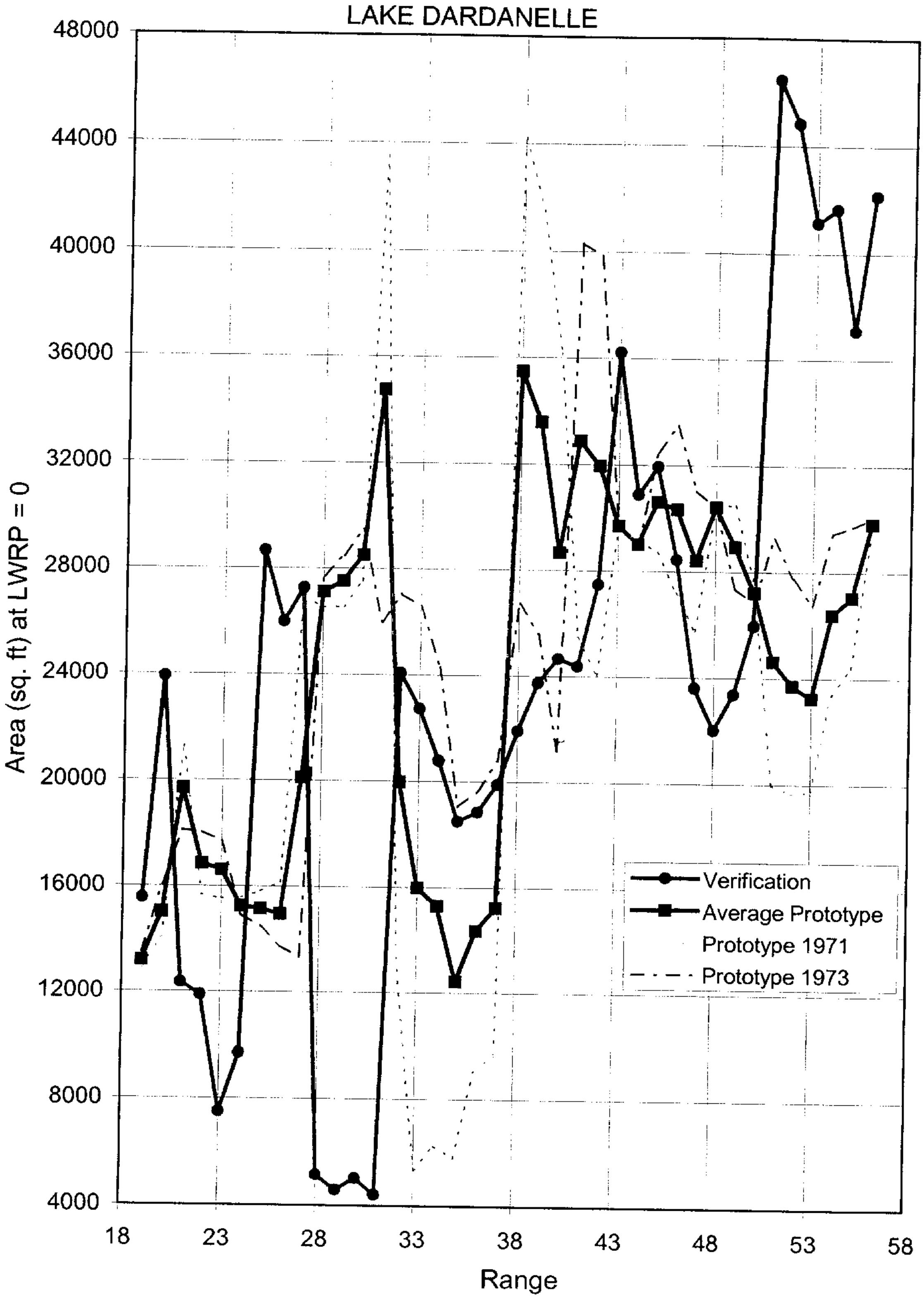

Figure B-8.2b Cross-Section Area by Range, Lake Dardanelle

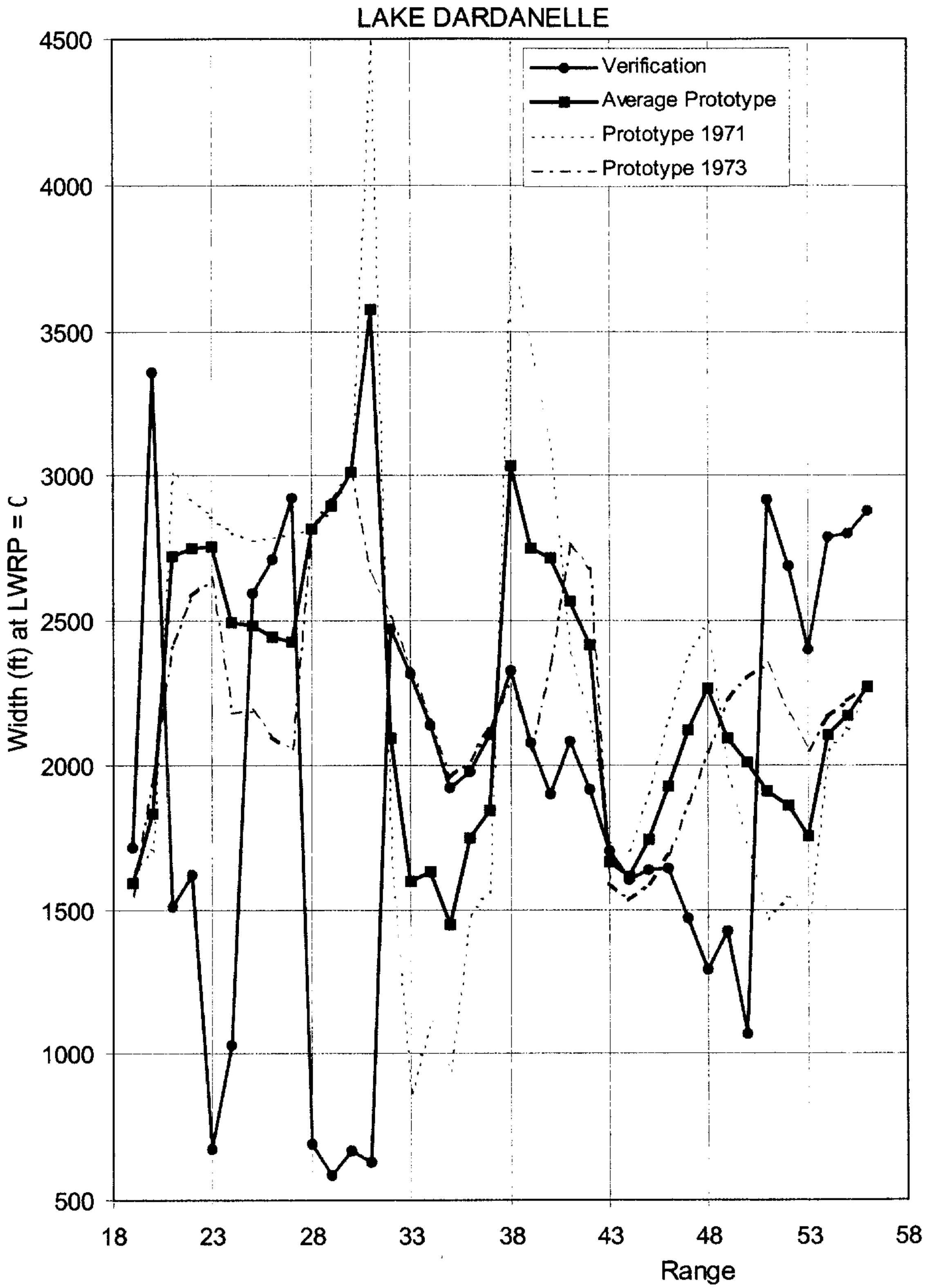

Figure B-8.2c Top Width by Range, Lake Dardanelle

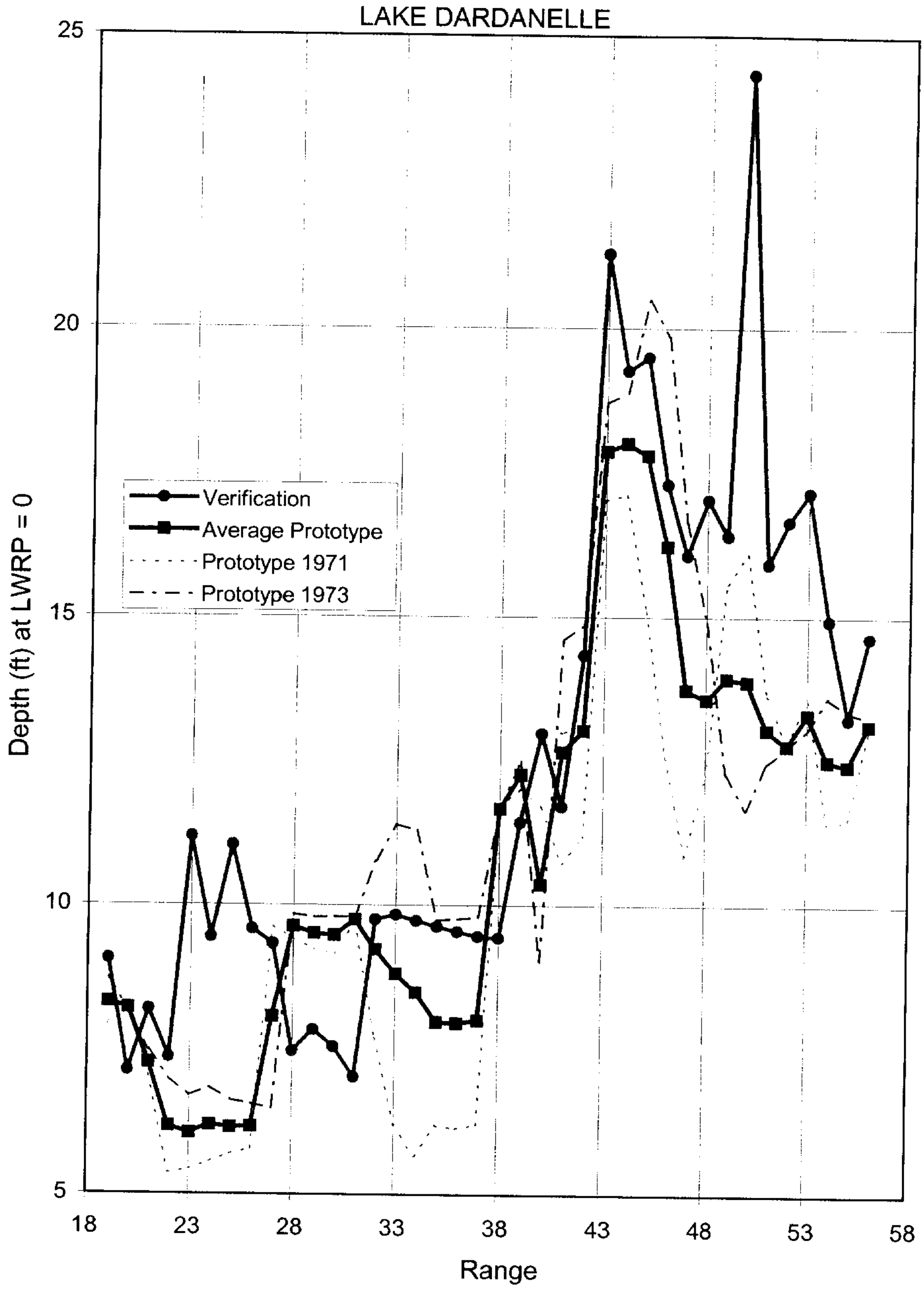

Figure B-8.2d Hydraulic Depth by Range, Lake Dardanelle

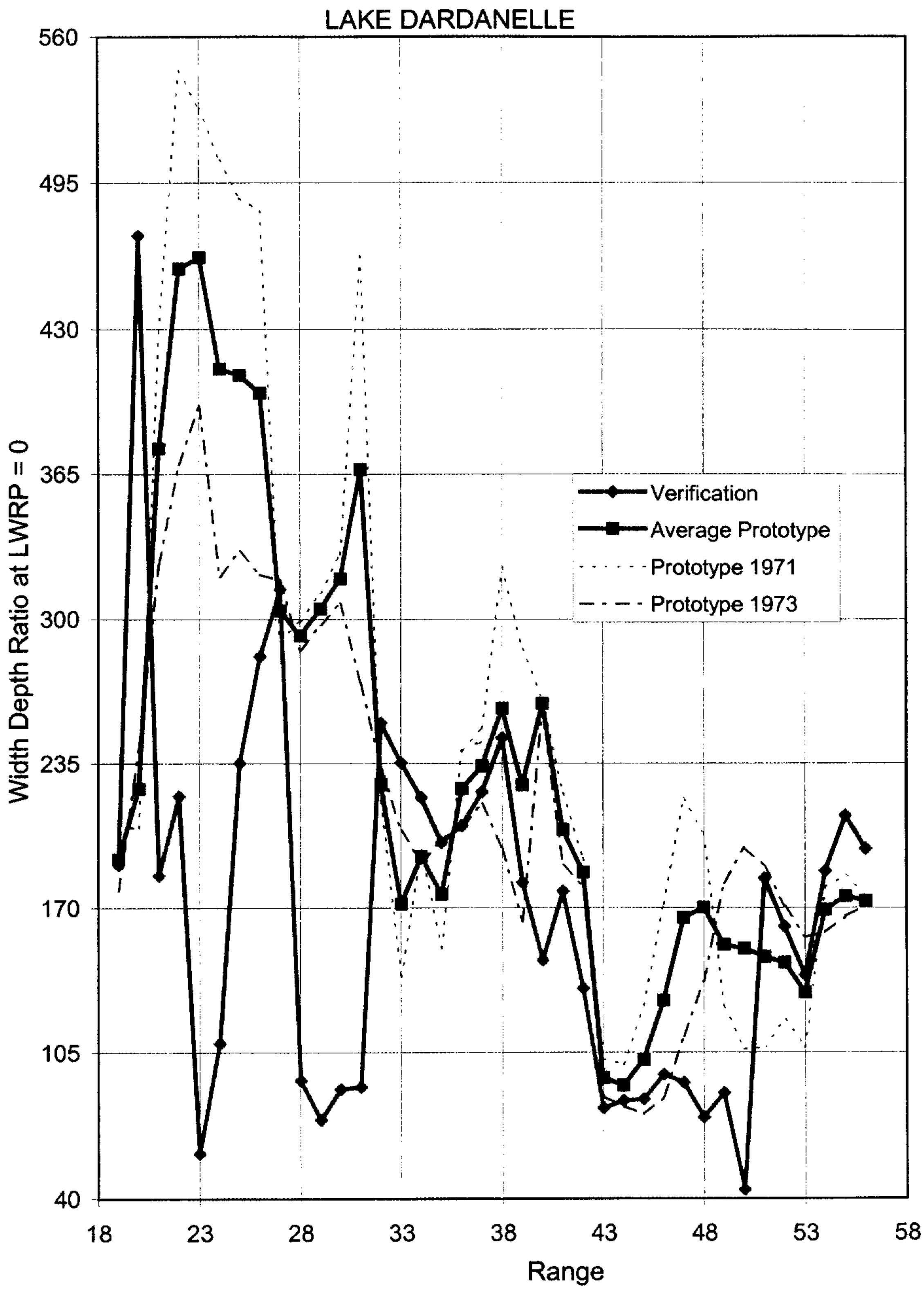

Figure B-8.2e Width/Depth Ratio by Range, Lake Dardanelle

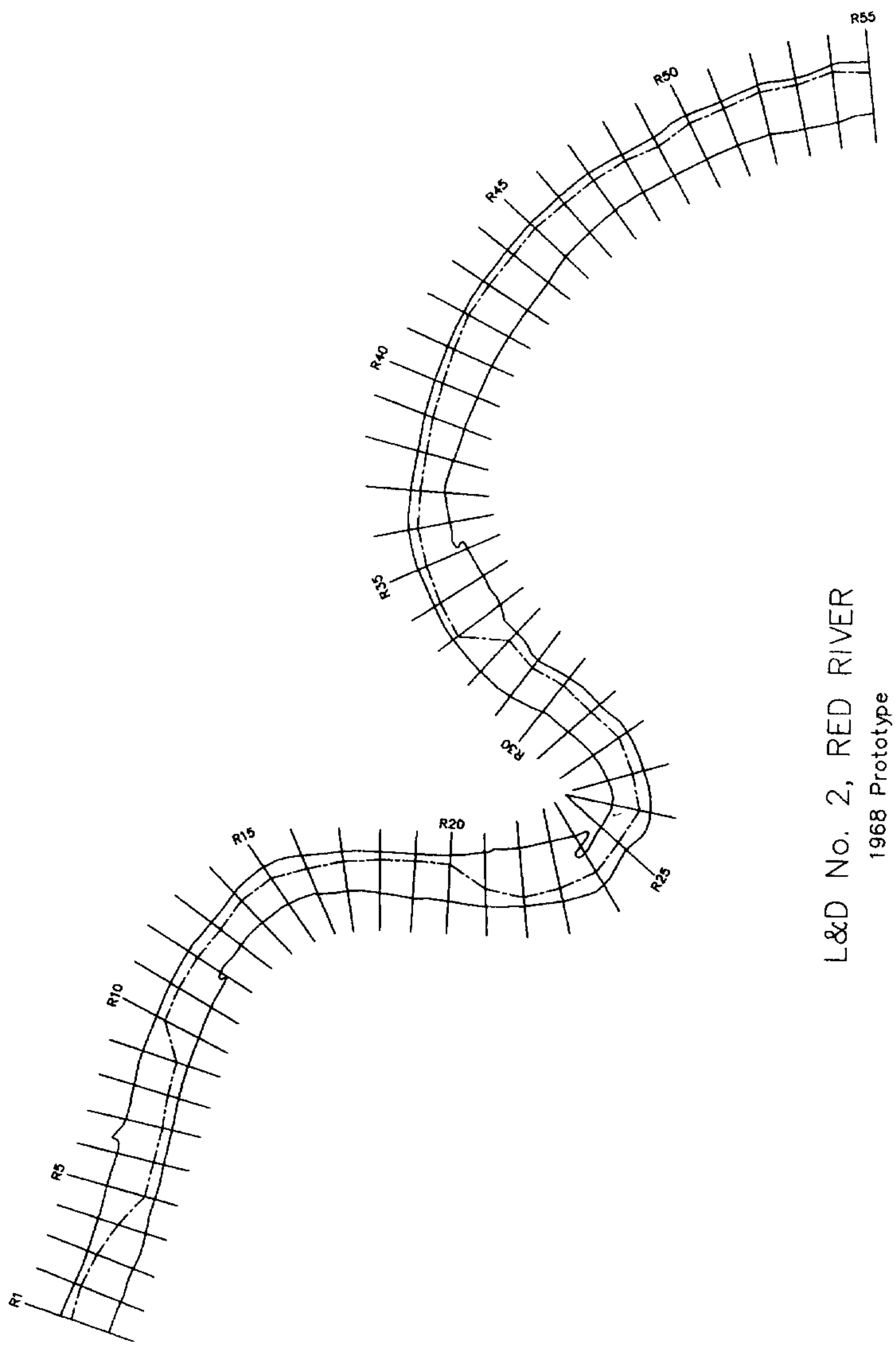

Figure B-9.1a Lock and Dam No. 2, Red River Model Plan View

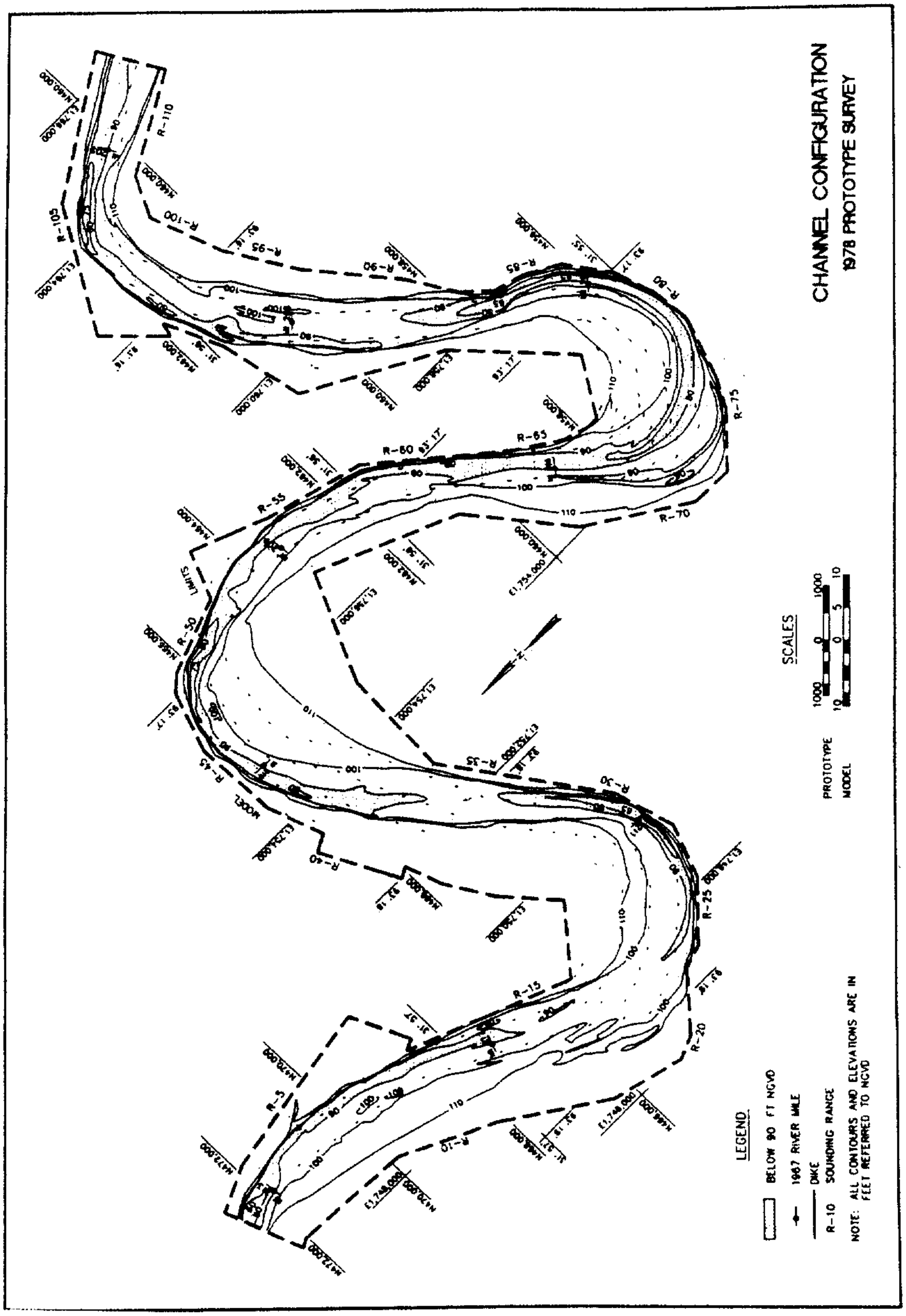

Figure B-9.1b L &D No. 2 1968 Prototype Survey

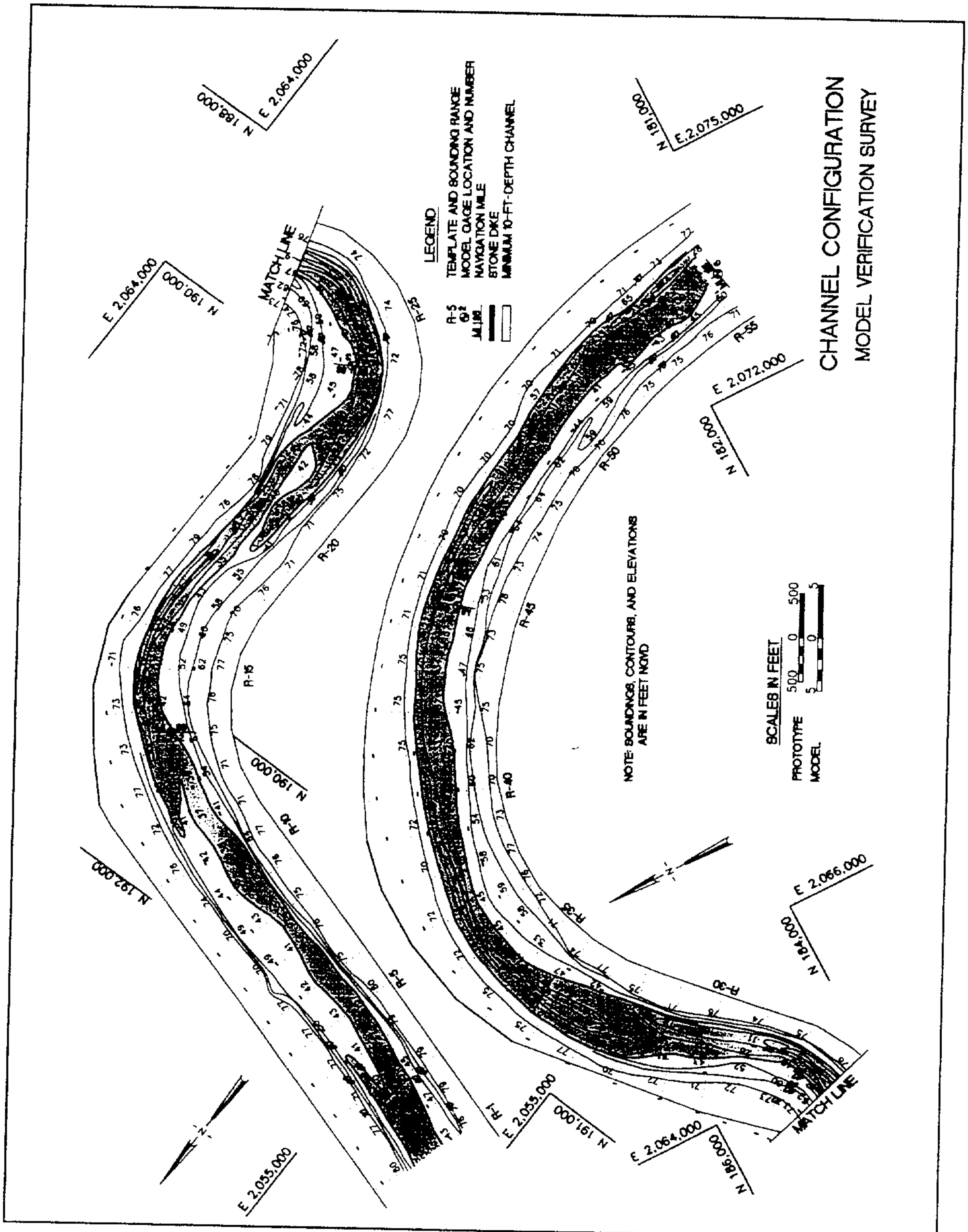

Figure B-9.1c L &D No. 2 Verification Test Survey

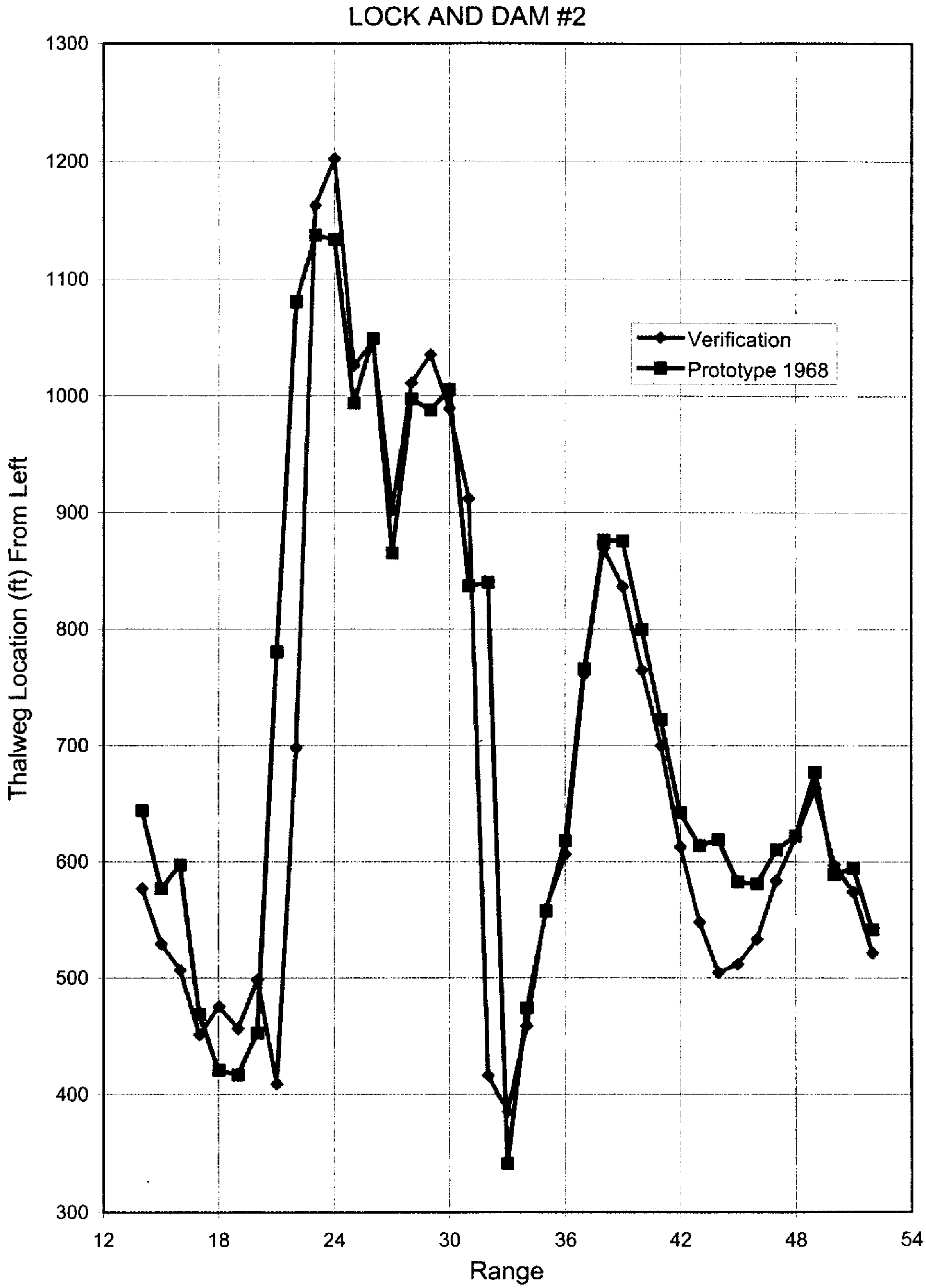

Figure B-9.2a Thalweg Location From Left by Range, Lock and Dam 2

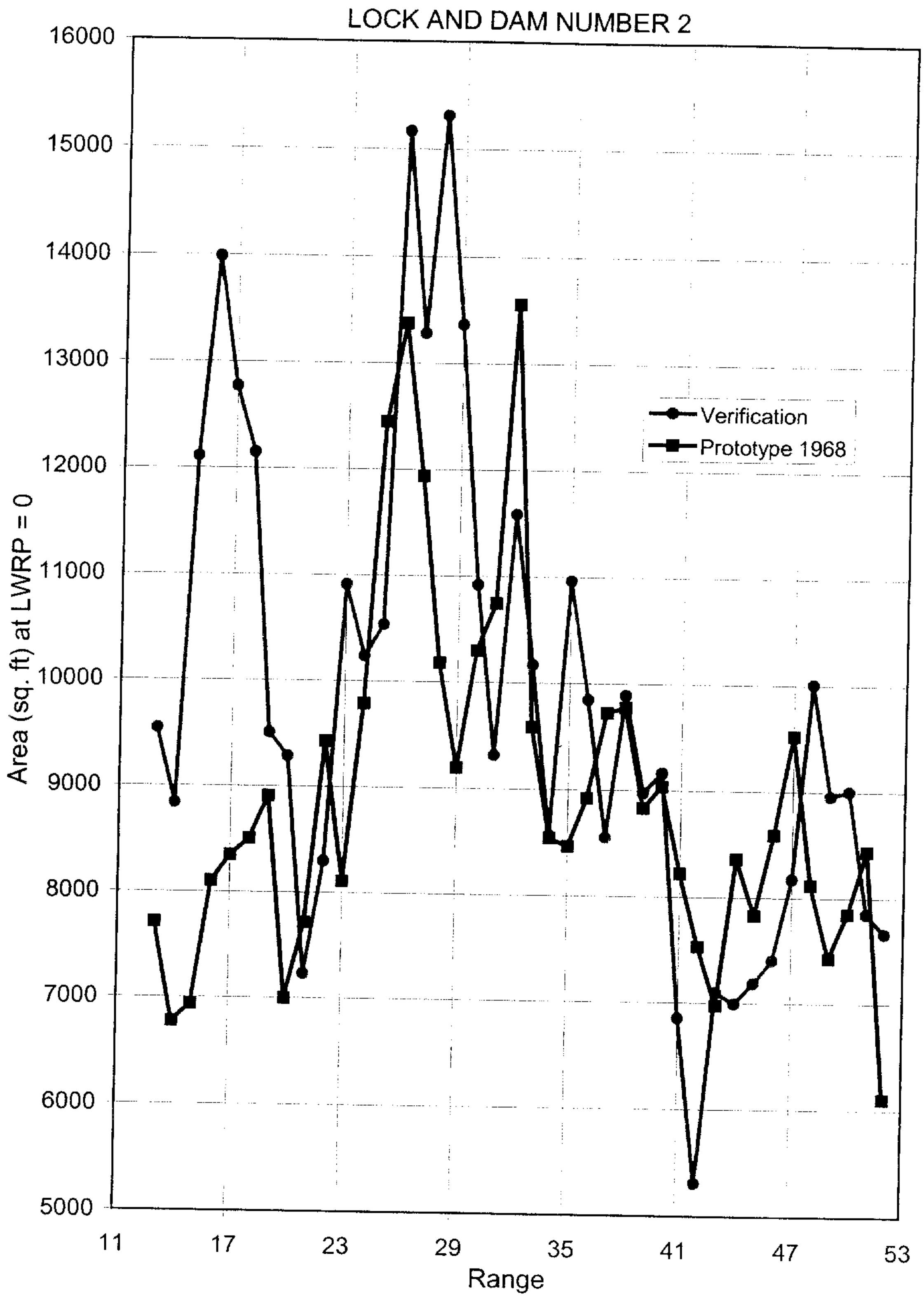

Figure B-9.2b Cross-Section Area by Range, Lock and Dam 2

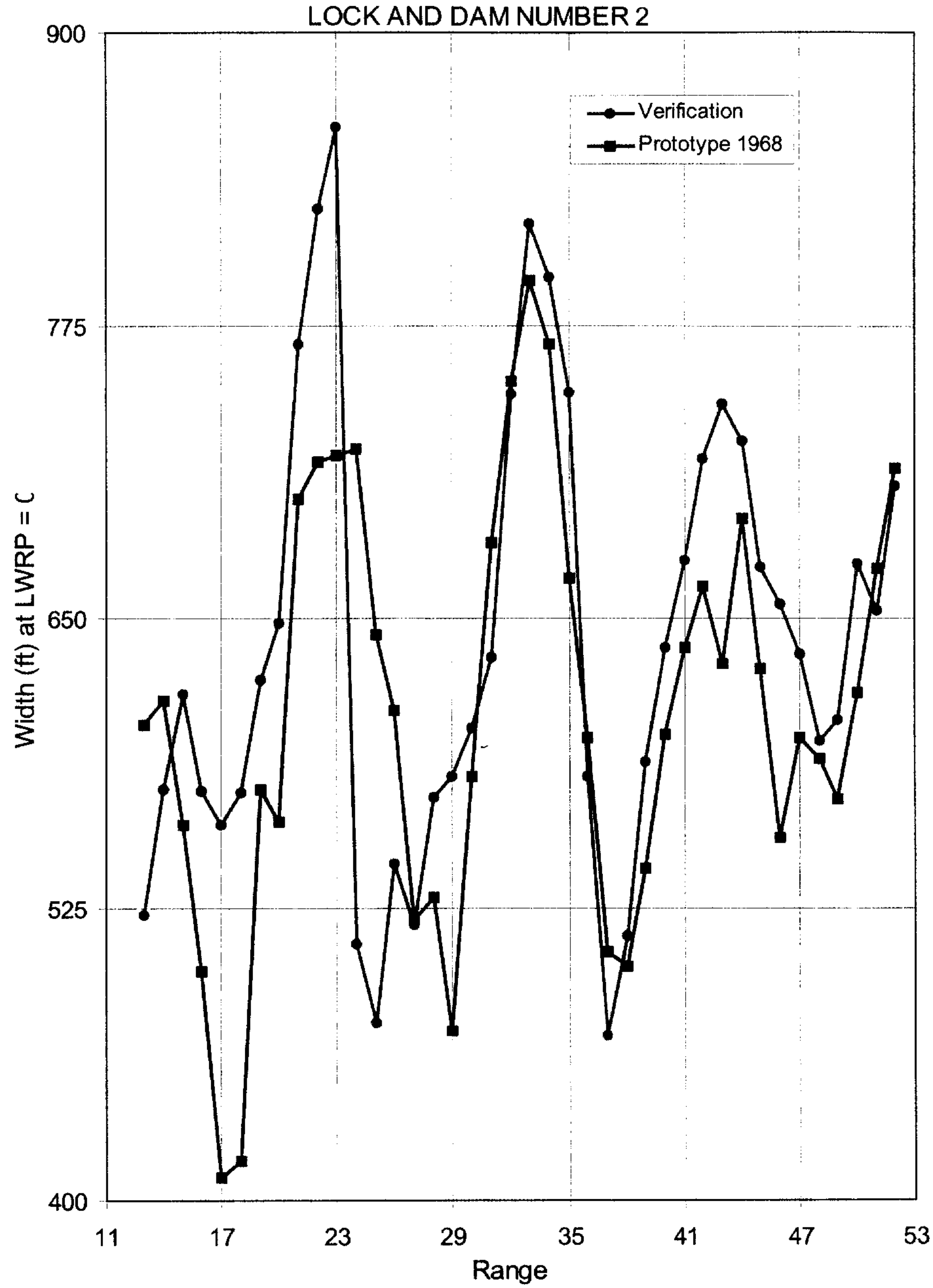

Figure B-9.2c Top Width by Range, Lock and Dam 2

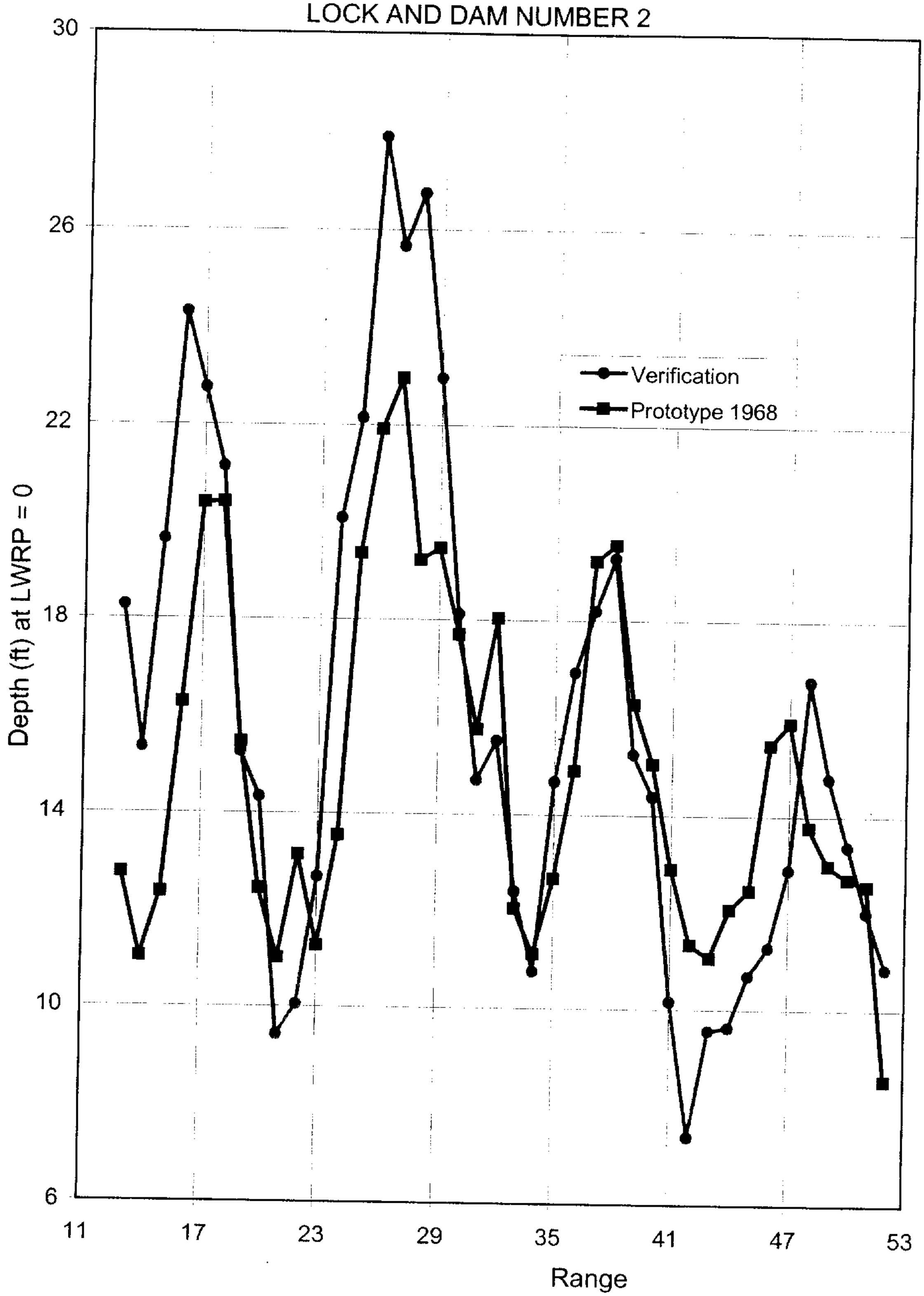

Figure B-9.2d Hydraulic Depth by Range, Lock and Dam 2

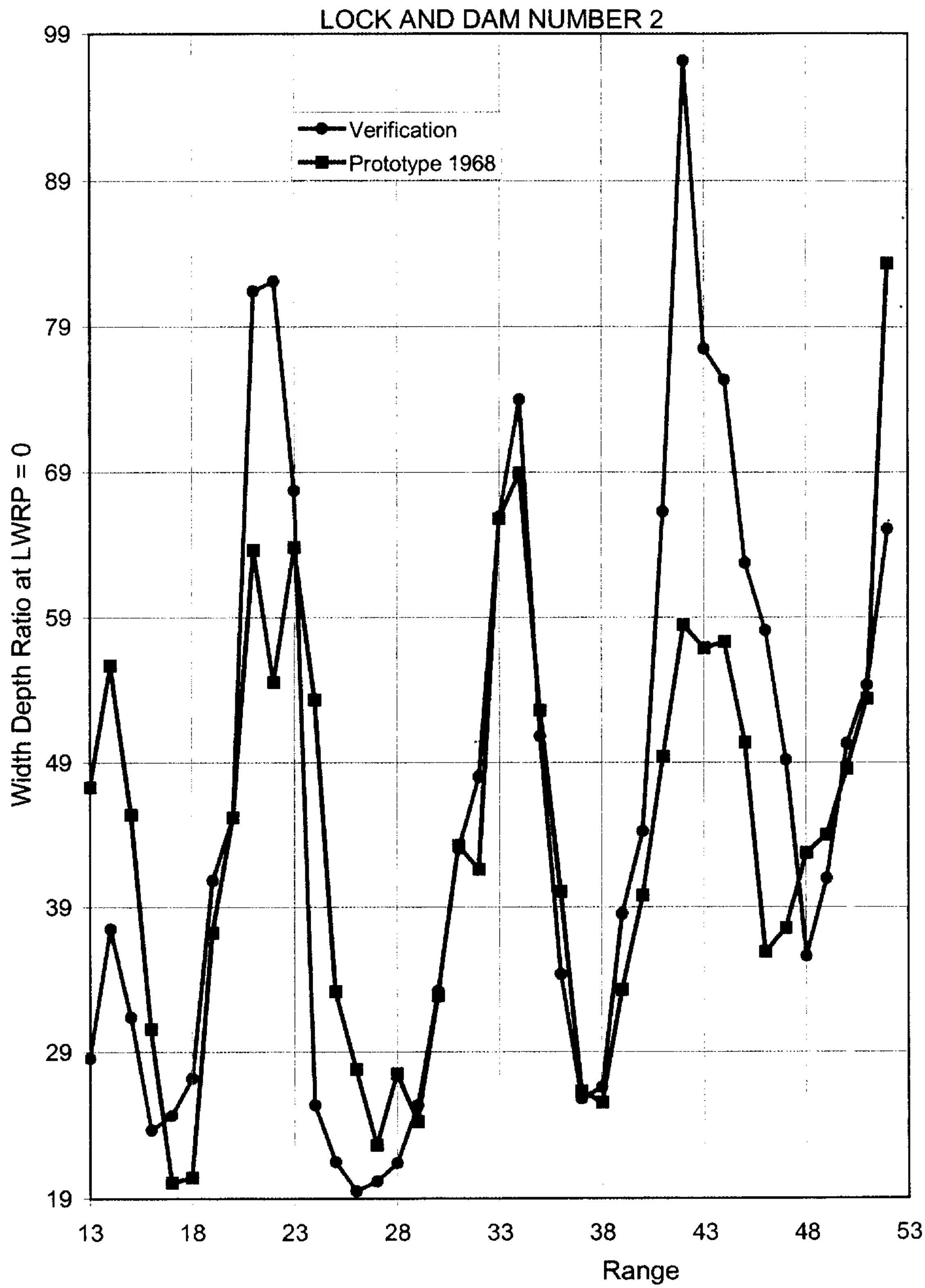

Figure B-9.2e Width/Depth Ratio by Range, Lock and Dam 2

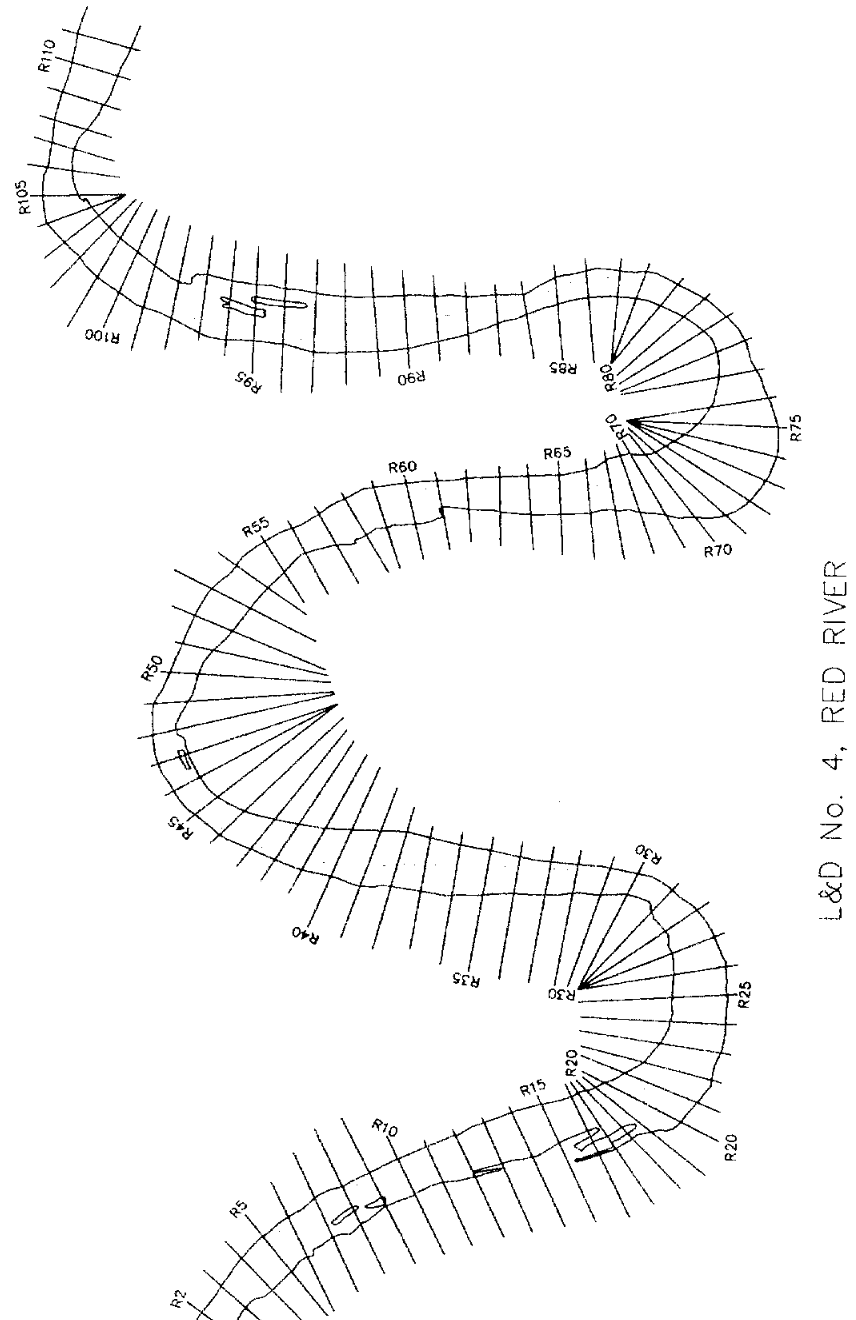

Figure B-10.1a Lock and Dam No. 4 Model Plan View

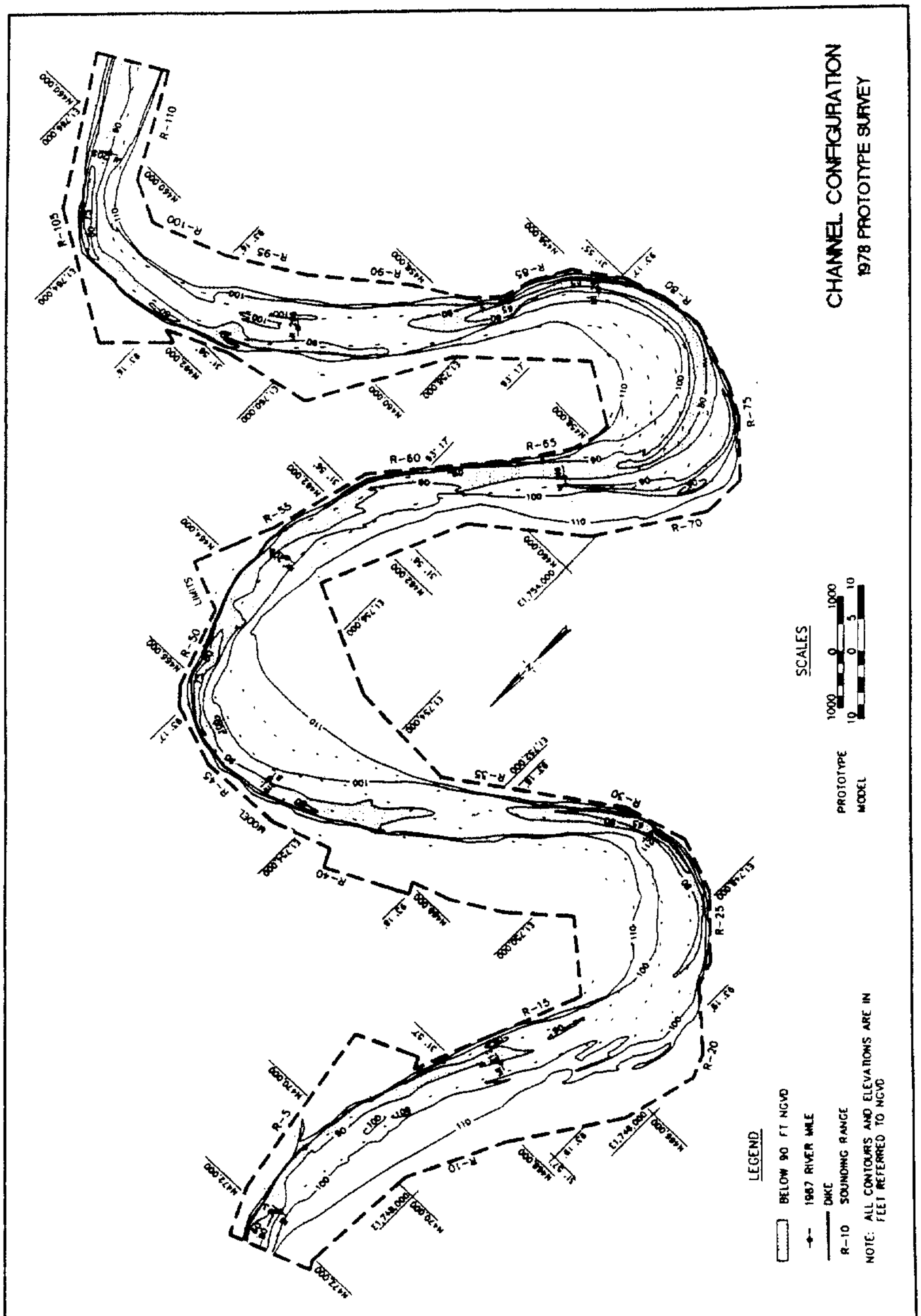

Figure B-10.1b L &D No. 4 1978 Prototype Survey

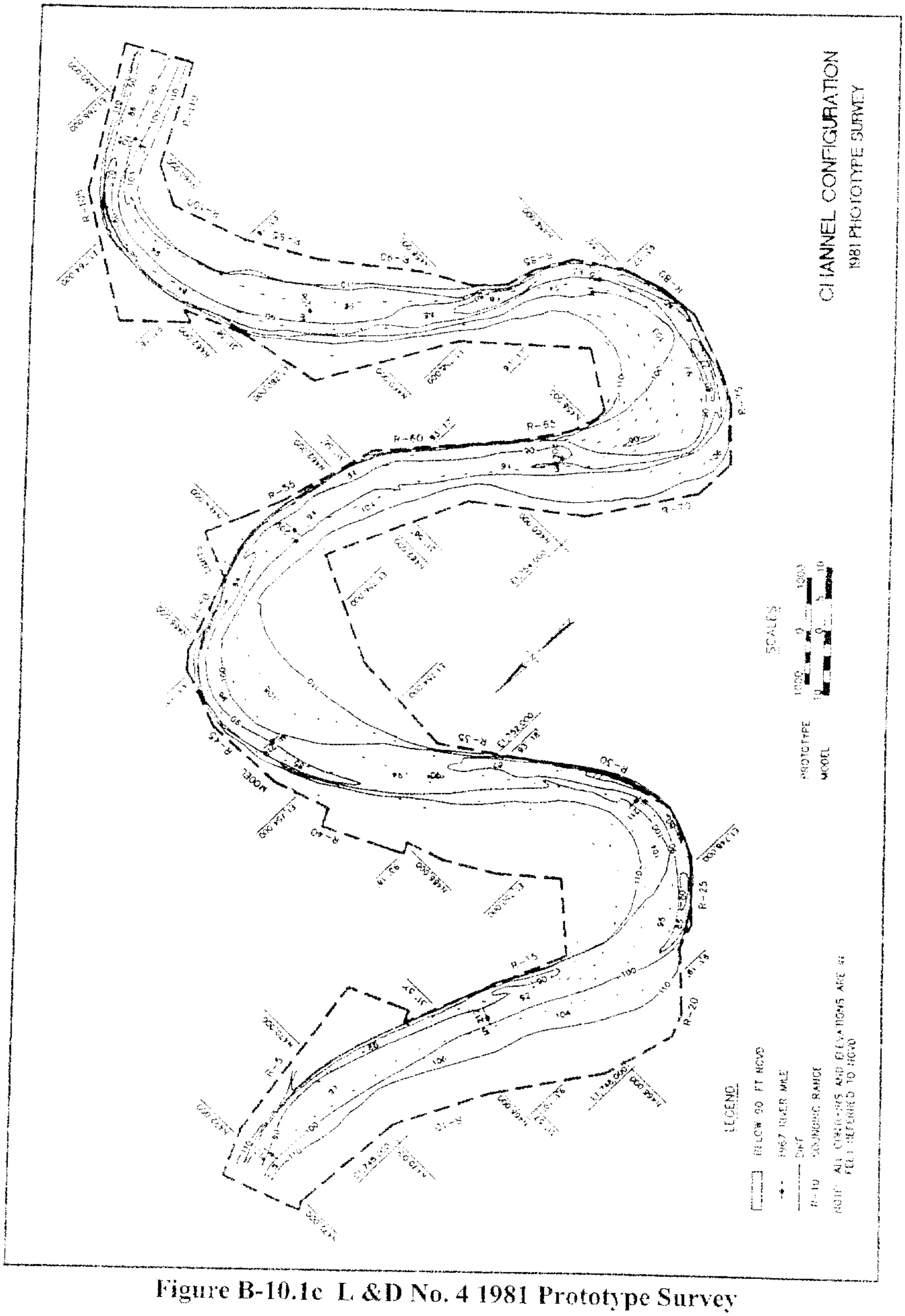

Figure B-10.1c L &D No. 4 1981 Prototype Survey

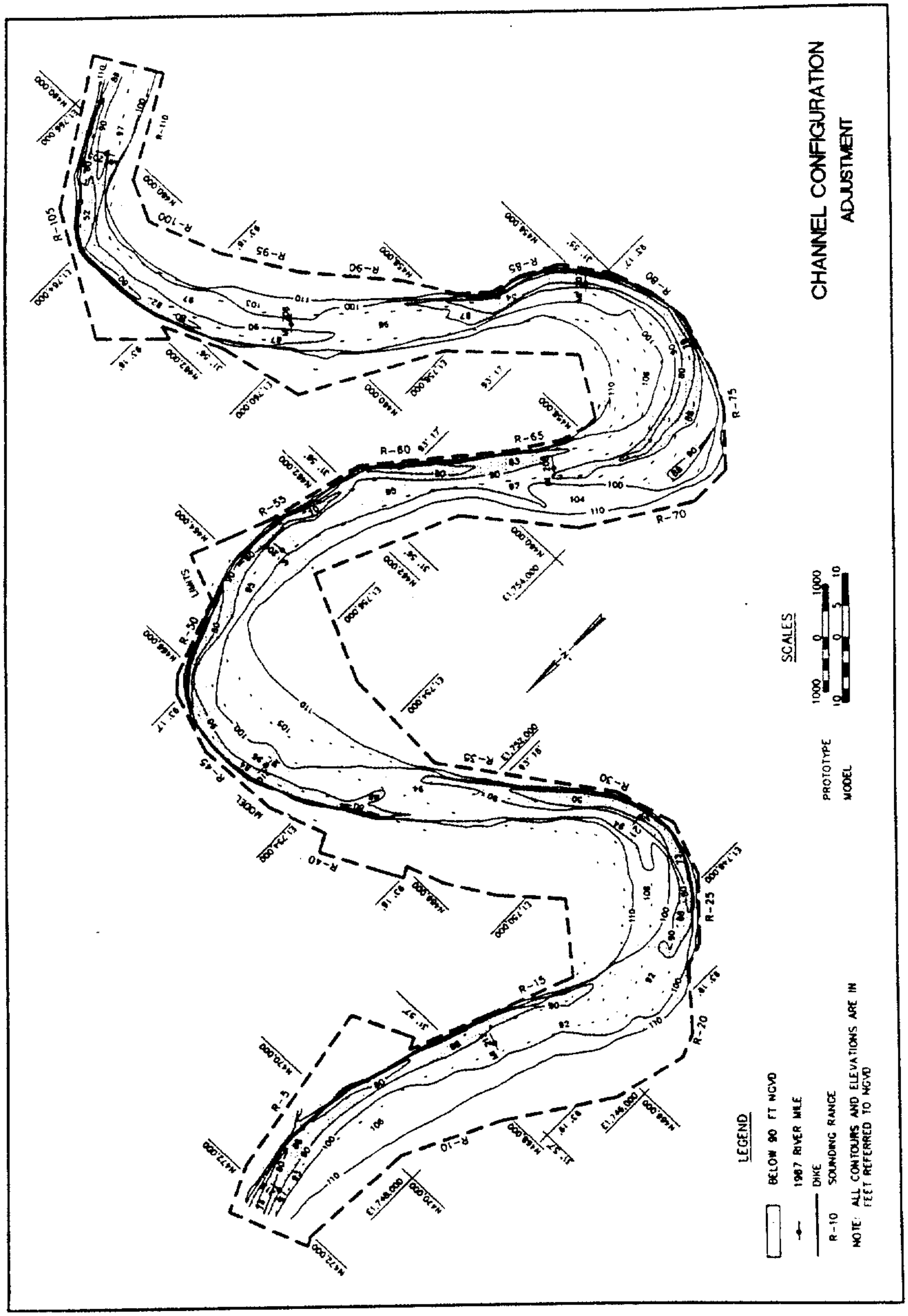

Figure B-10.1d L &D No. 4 Verification Test Survey

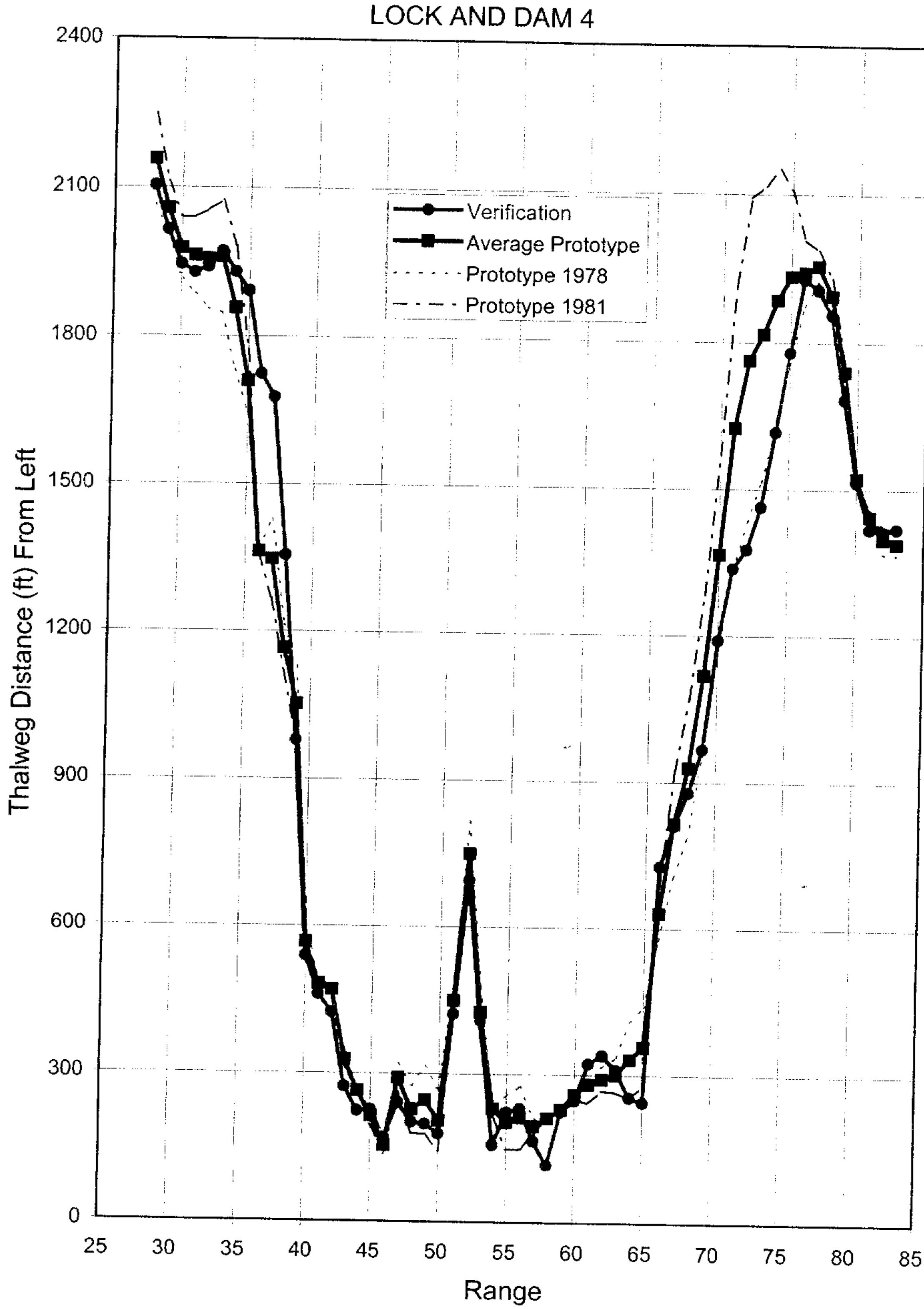

Figure B-10.2a Thalweg Location From Left by Range, Lock and Dam 4

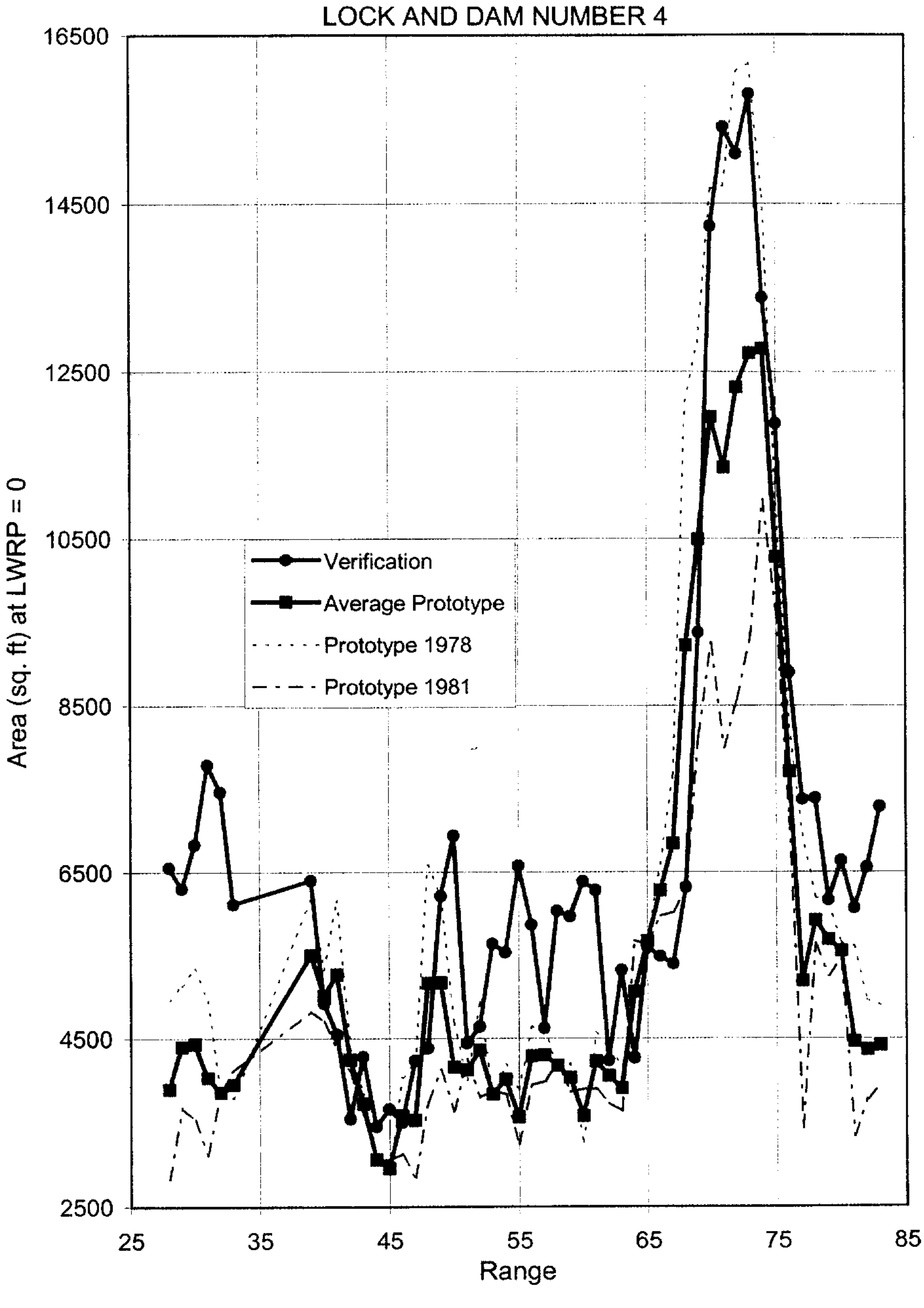

Figure B-10.2b Cross-Section Area by Range, Lock and Dam 4

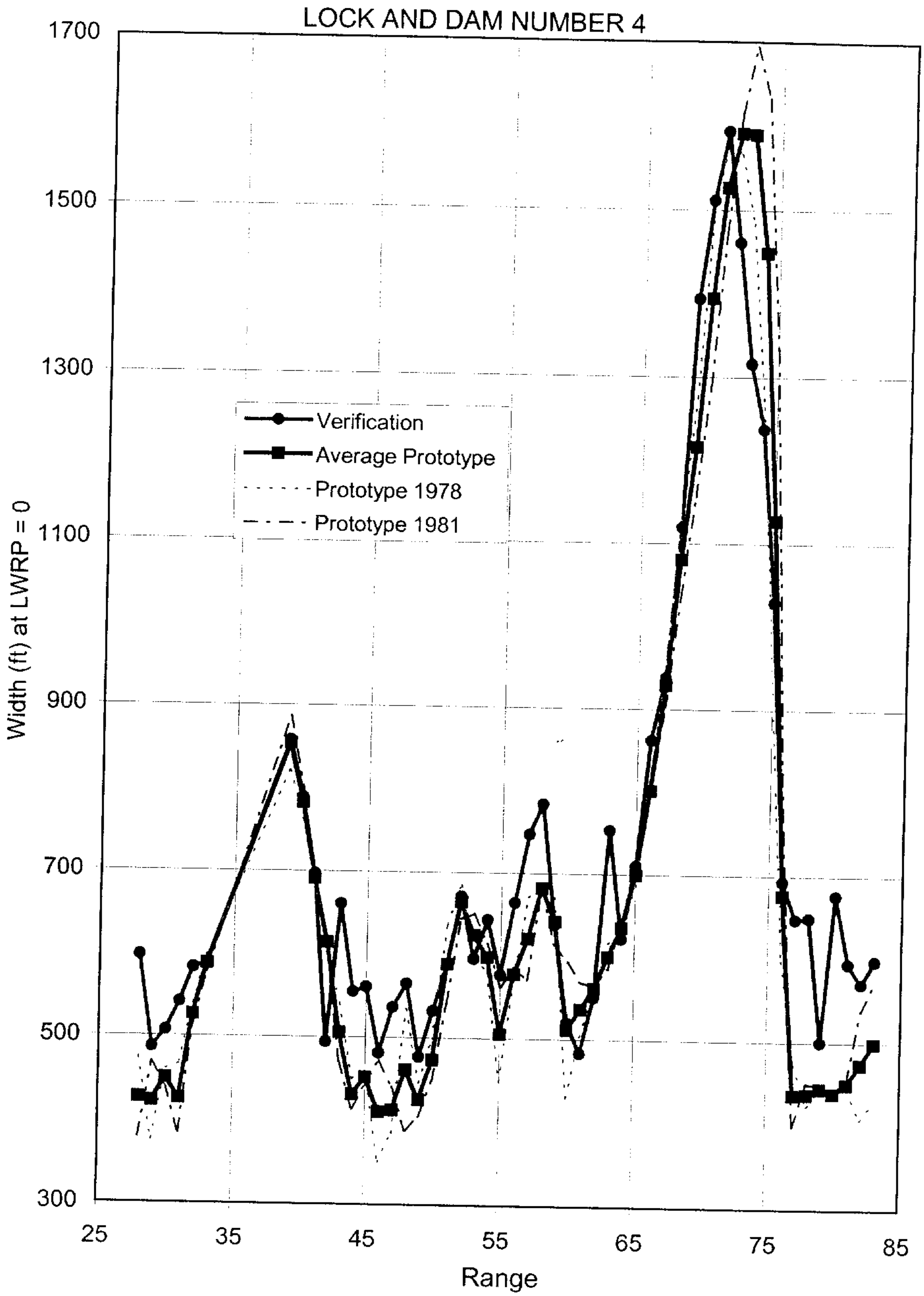

Figure B-10.2c Top Width by Range, Lock and Dam 4

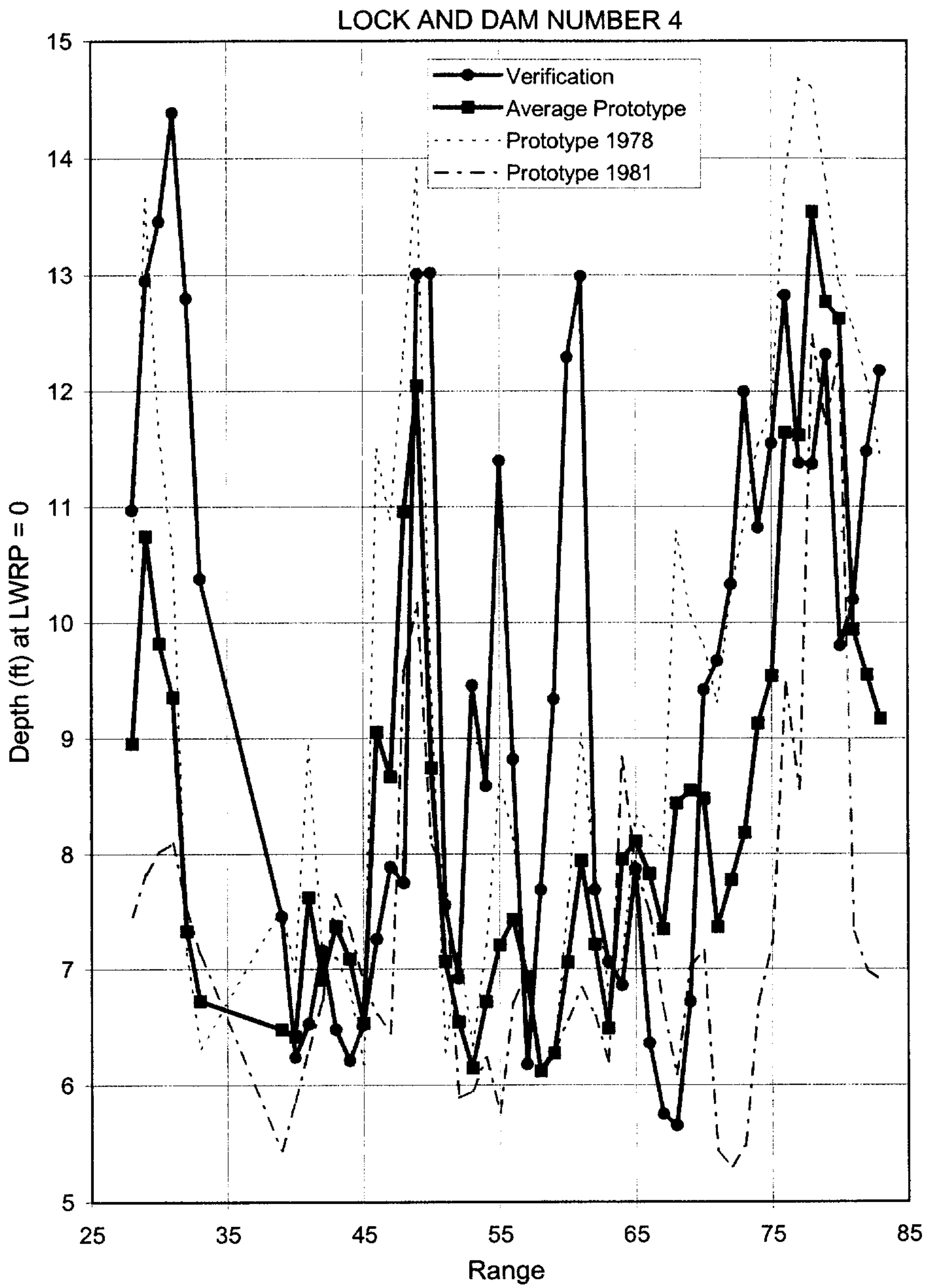

Figure B-10.2d Hydraulic Depth by Range, Lock and Dam 4

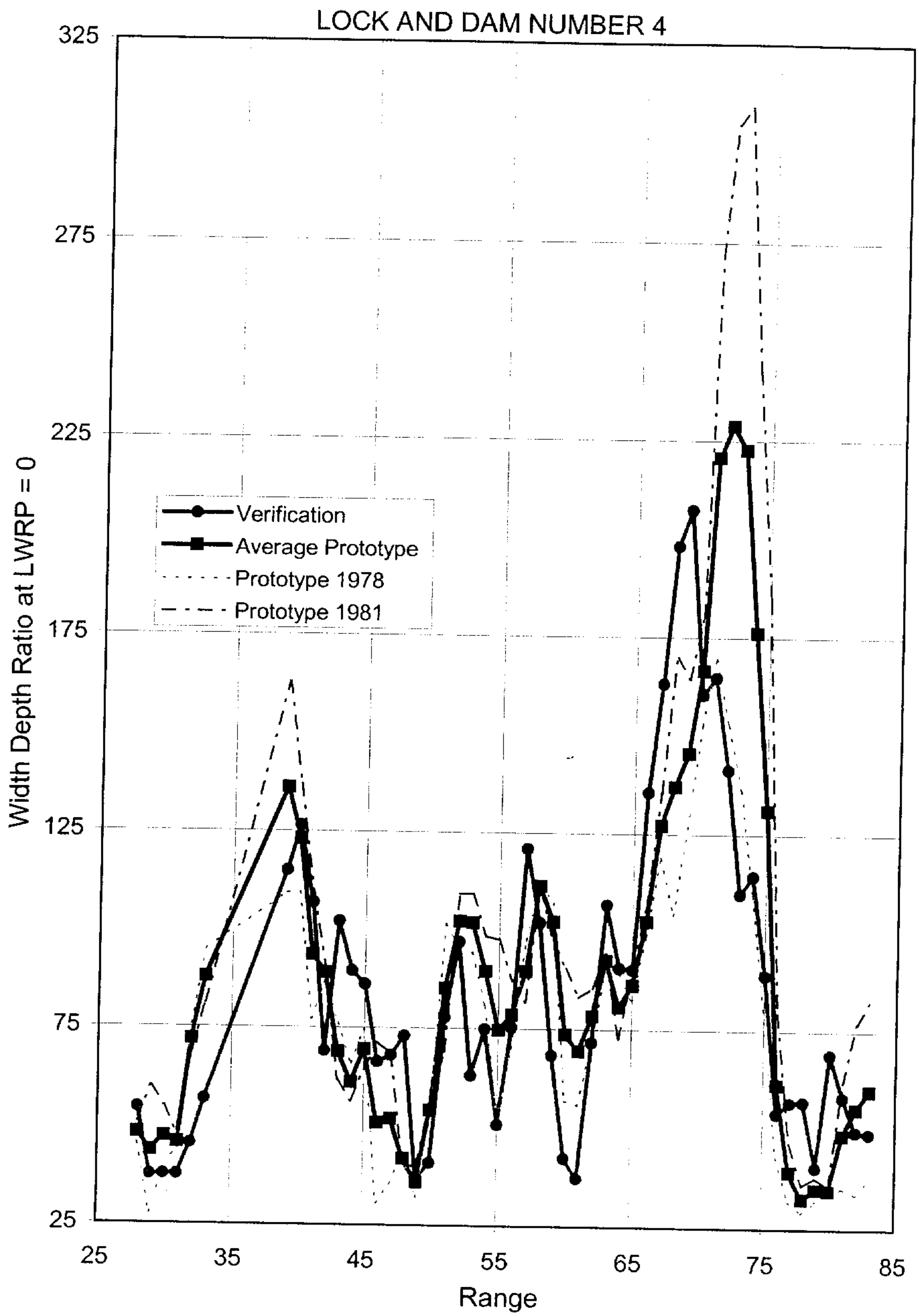

Figure B-10.2e Width/Depth Ratio by Range, Lock and Dam 4

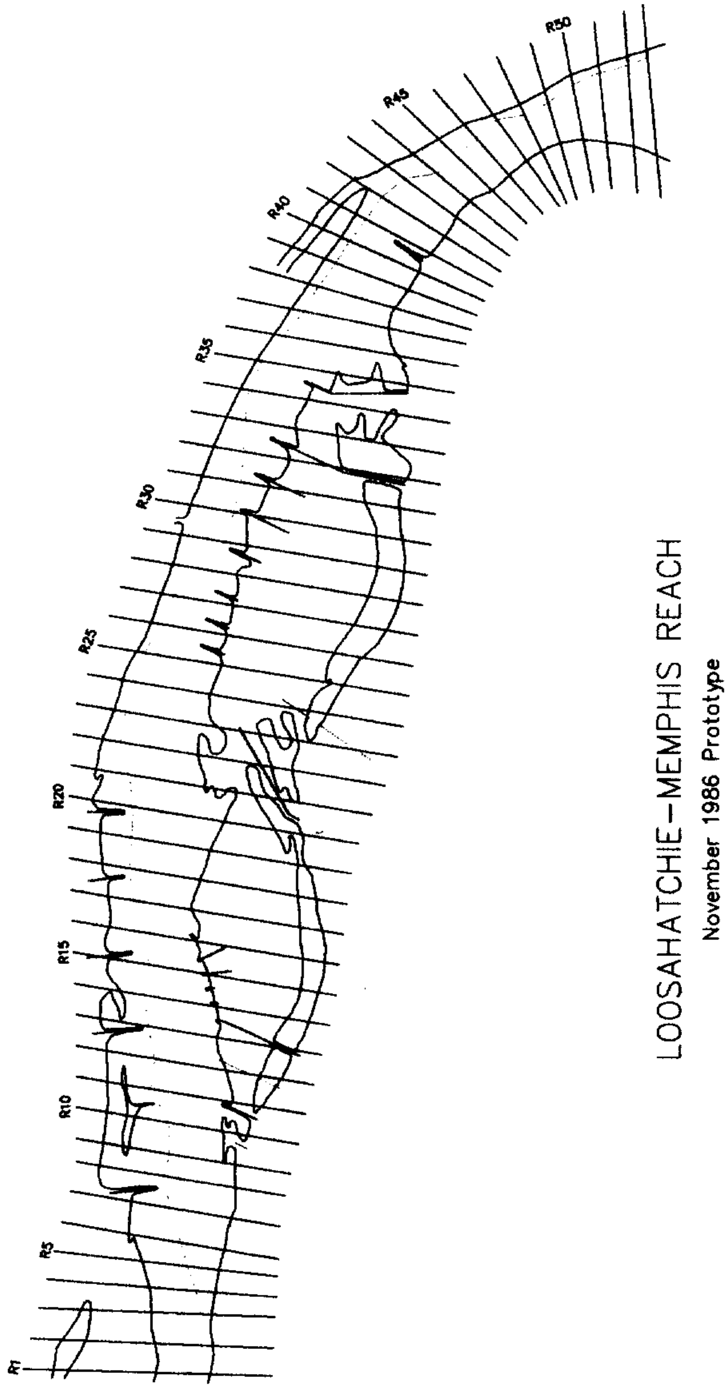

Figure B-11.1a Loosahatchie-Memphis Model Plan View

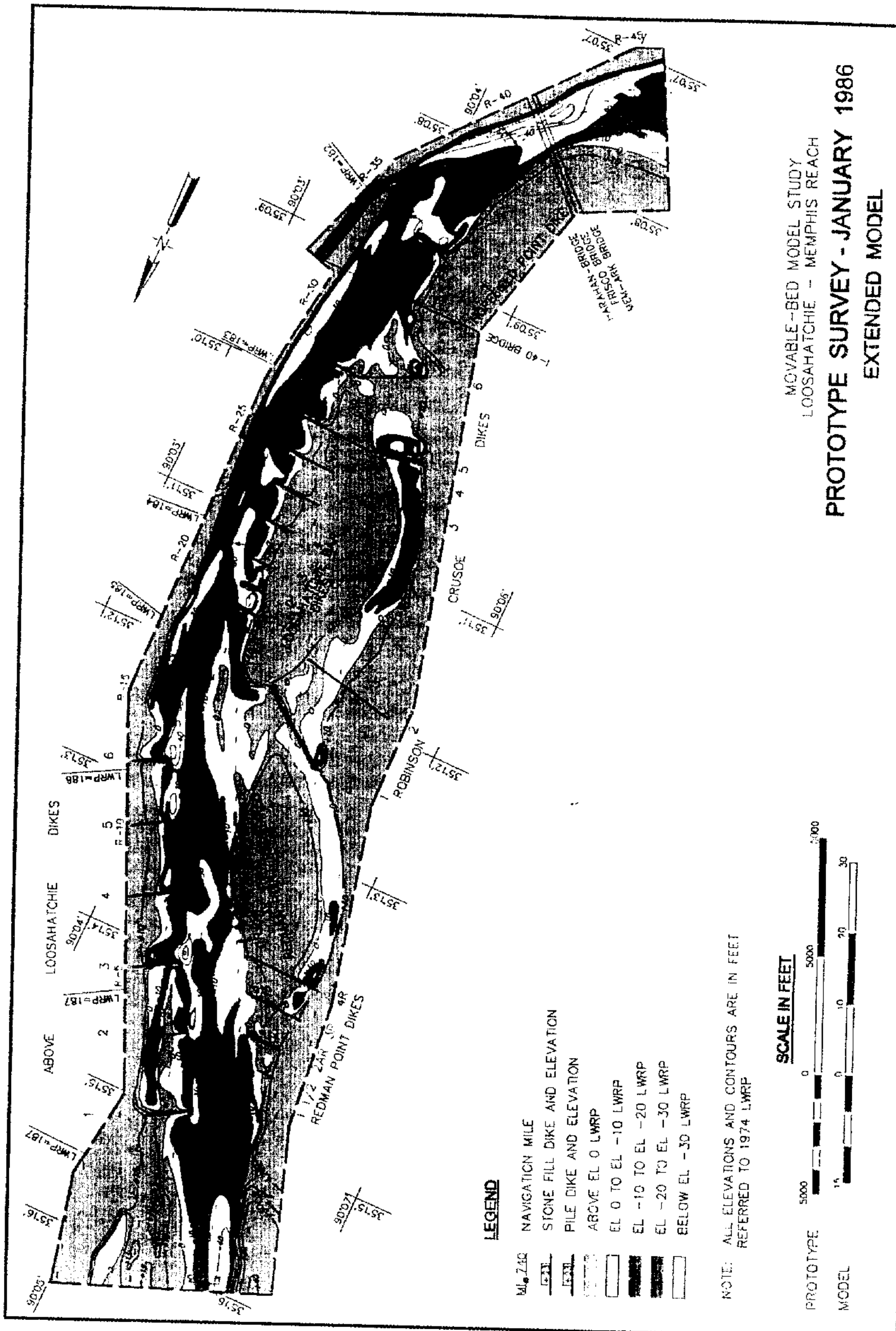

Figure B-11.1b January 1986 Prototype Survey, Loosahatchie-Memphis

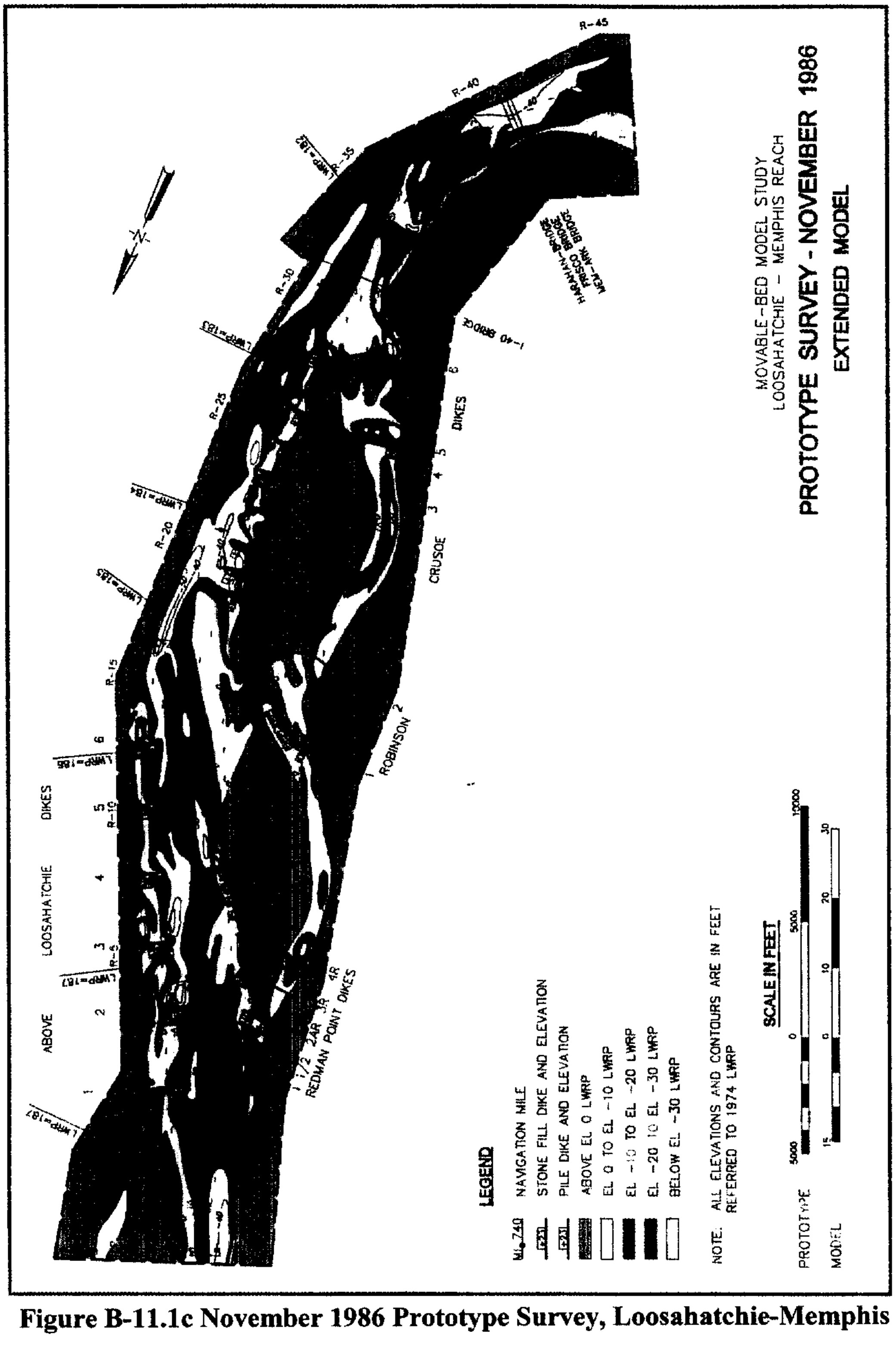

Figure B-11.1c November 1986 Prototype Survey, Loosahatchie-Memphis

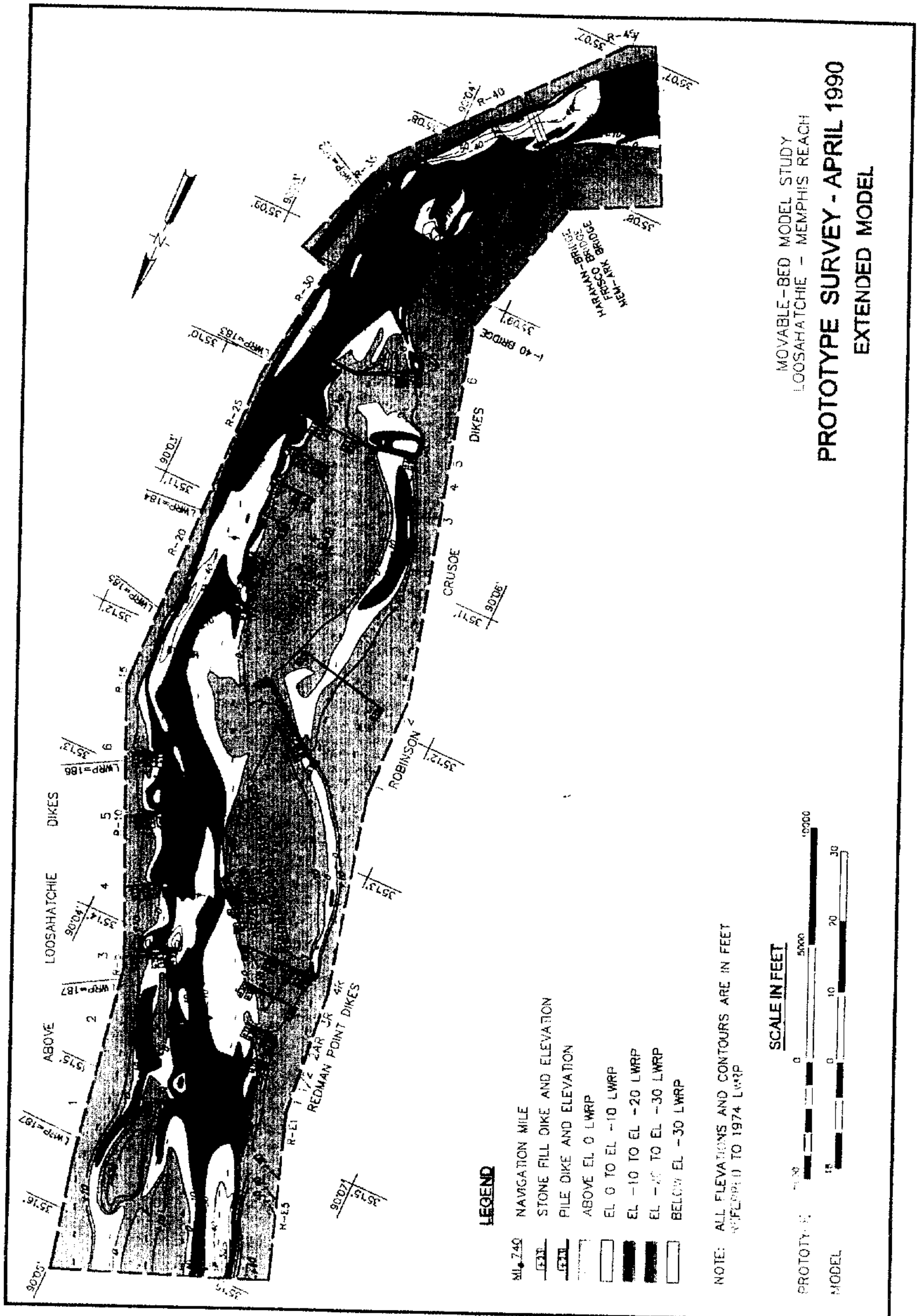

Figure B-11.1d April 1990 Prototype Survey, Loosahatchie-Memphis

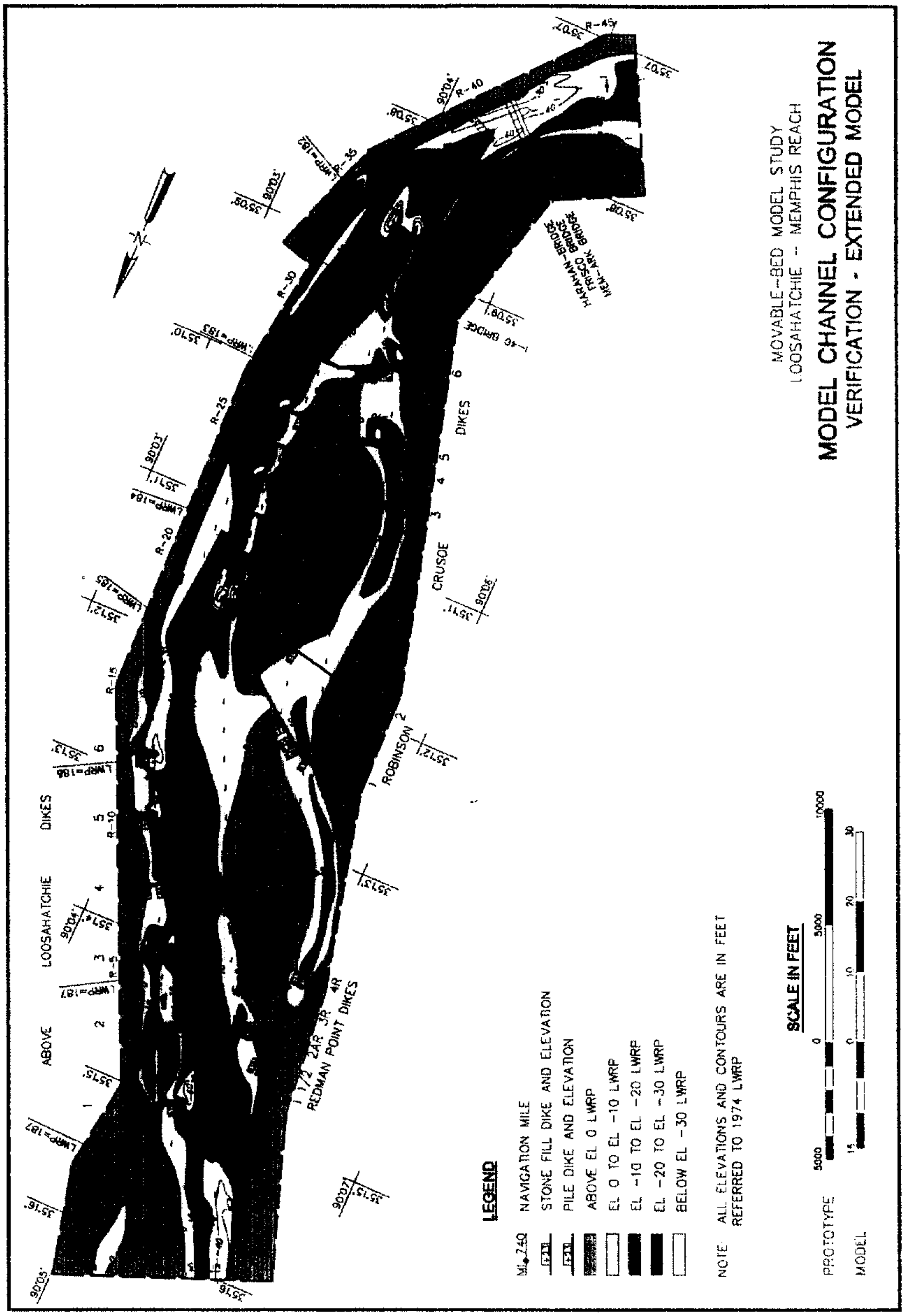

Figure B-11.1e Verification Survey, Loosahatchie-Memphis

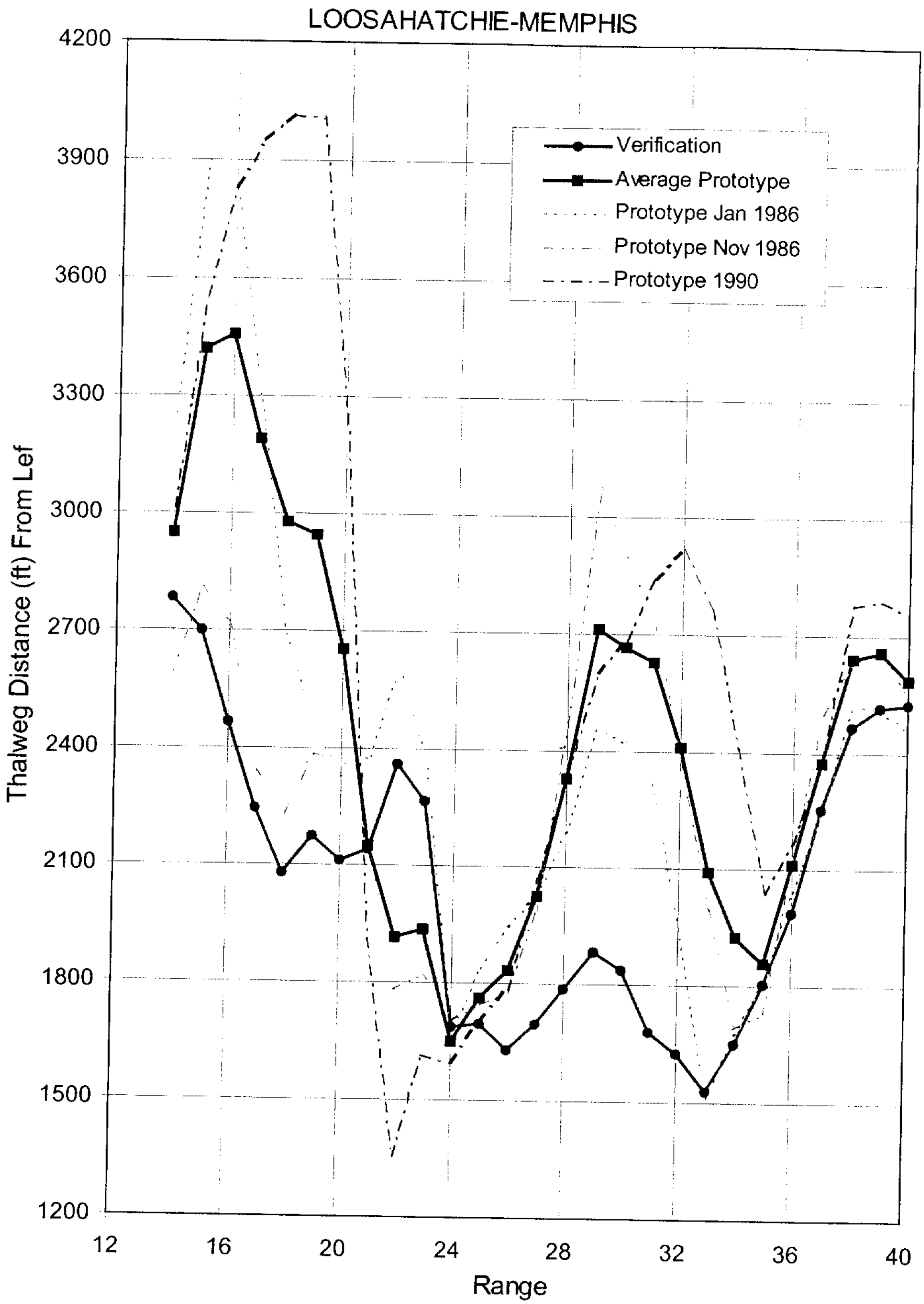

Figure B-11.2a Thalweg Location From Left by Range, Loosahatchie Memphis

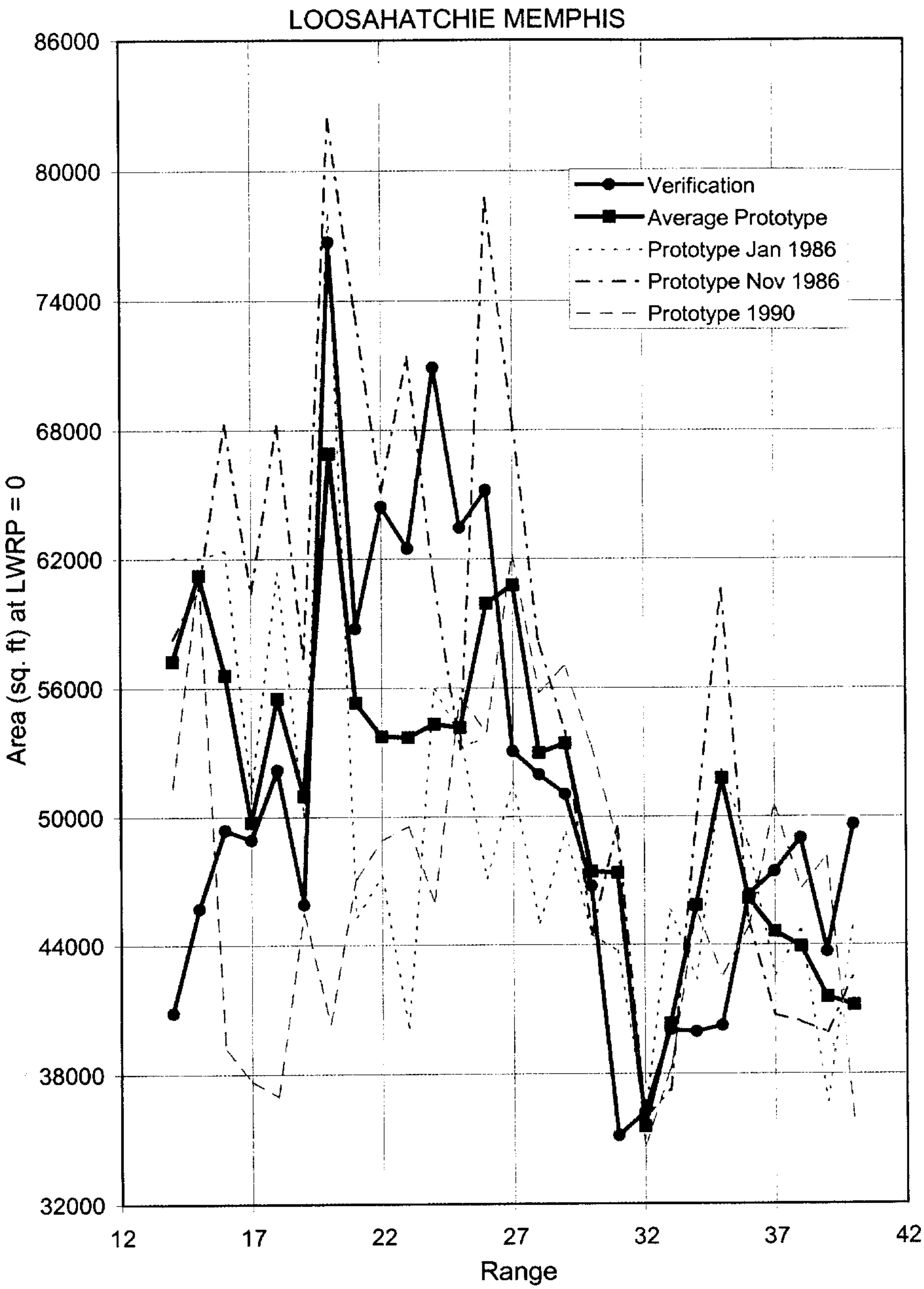

Figure B-11.2b Cross-Section Area by Range, Loosahatchie Memphis

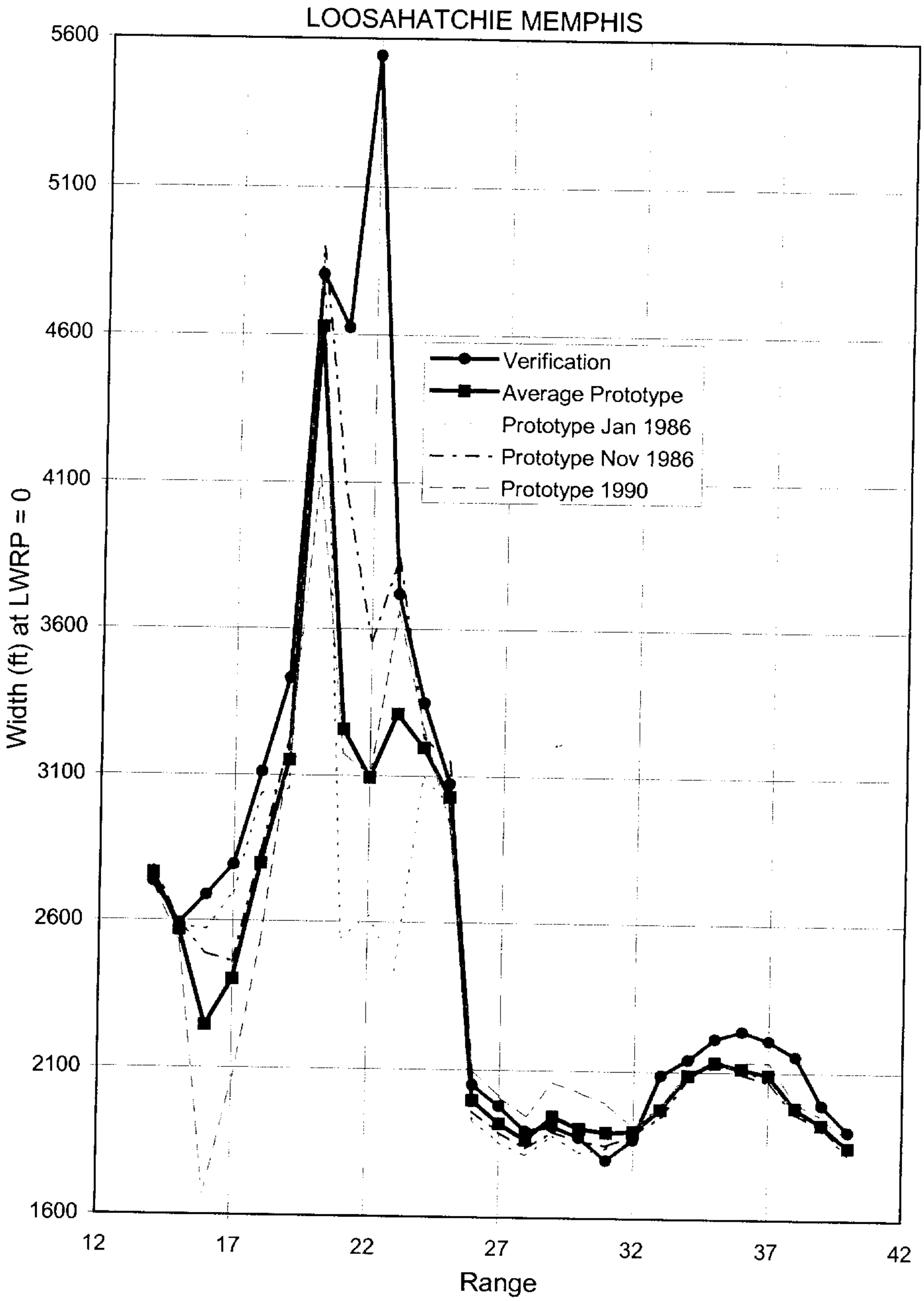

Figure B-11.2c Top Width by Range, Loosahatchie Memphis

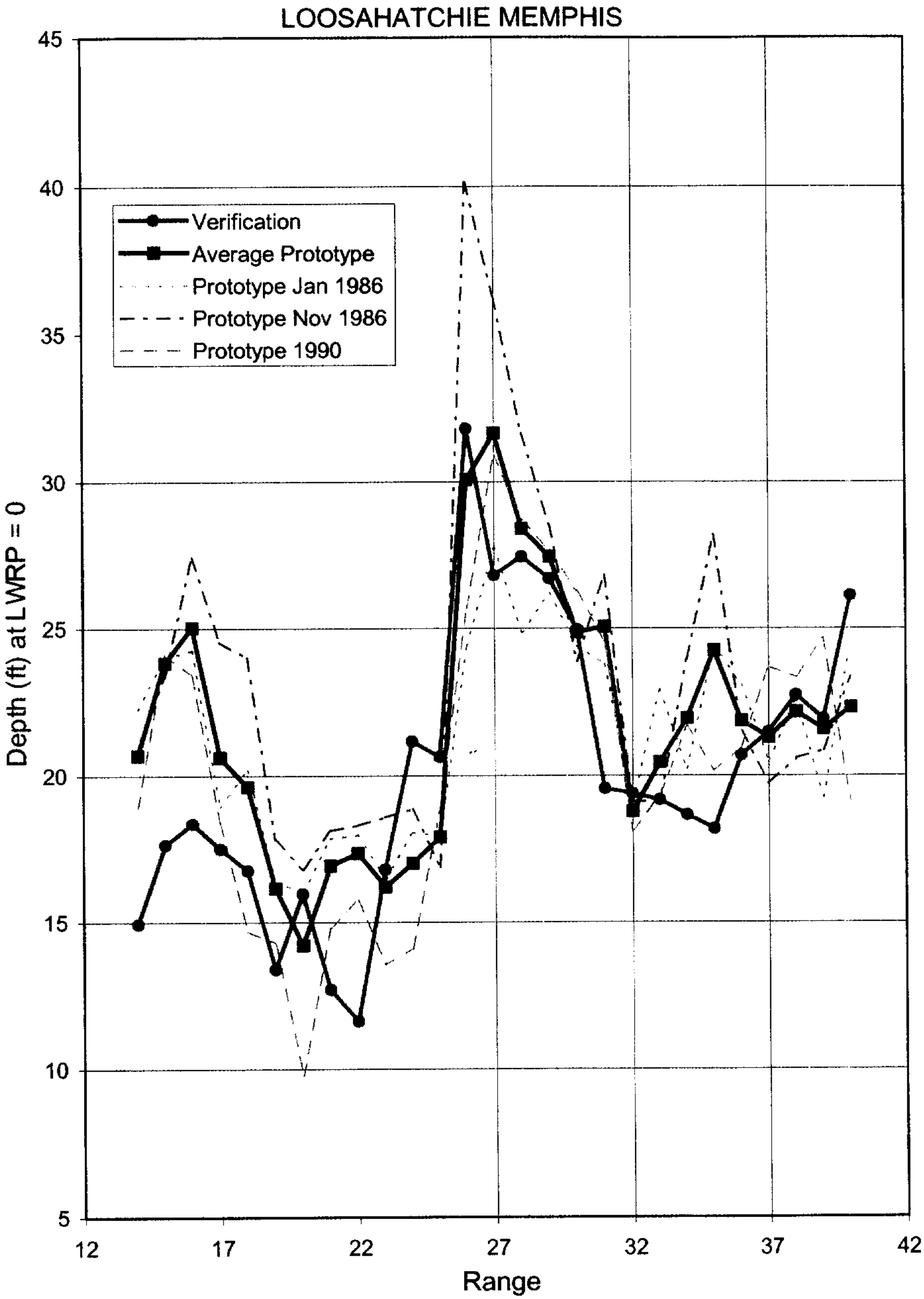

Figure B-11.2d Hydraulic Depth by Range, Loosahatchie Memphis

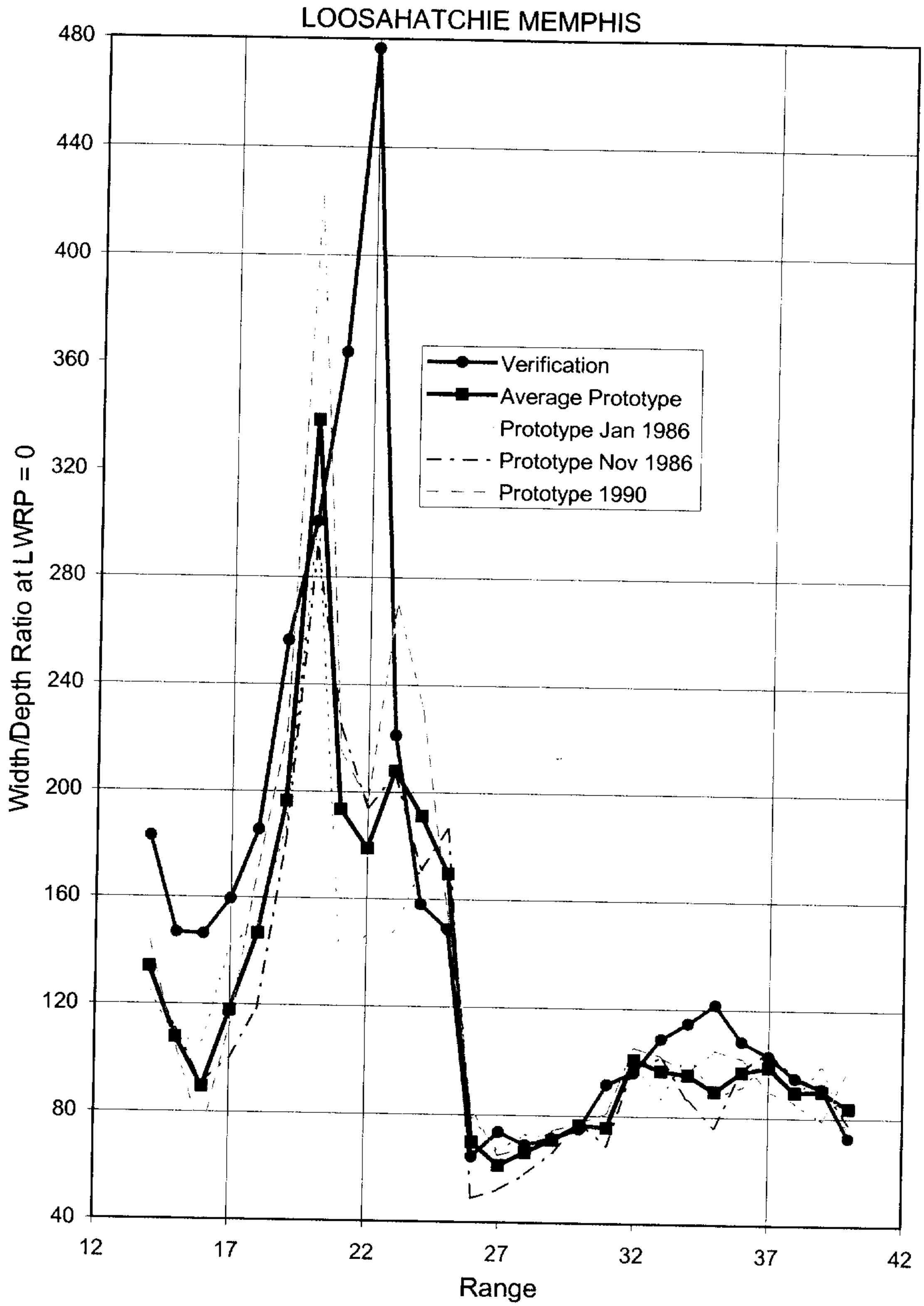

Figure B-11.2e Width/Depth Ratio by Range, Loosahatchie Memphis

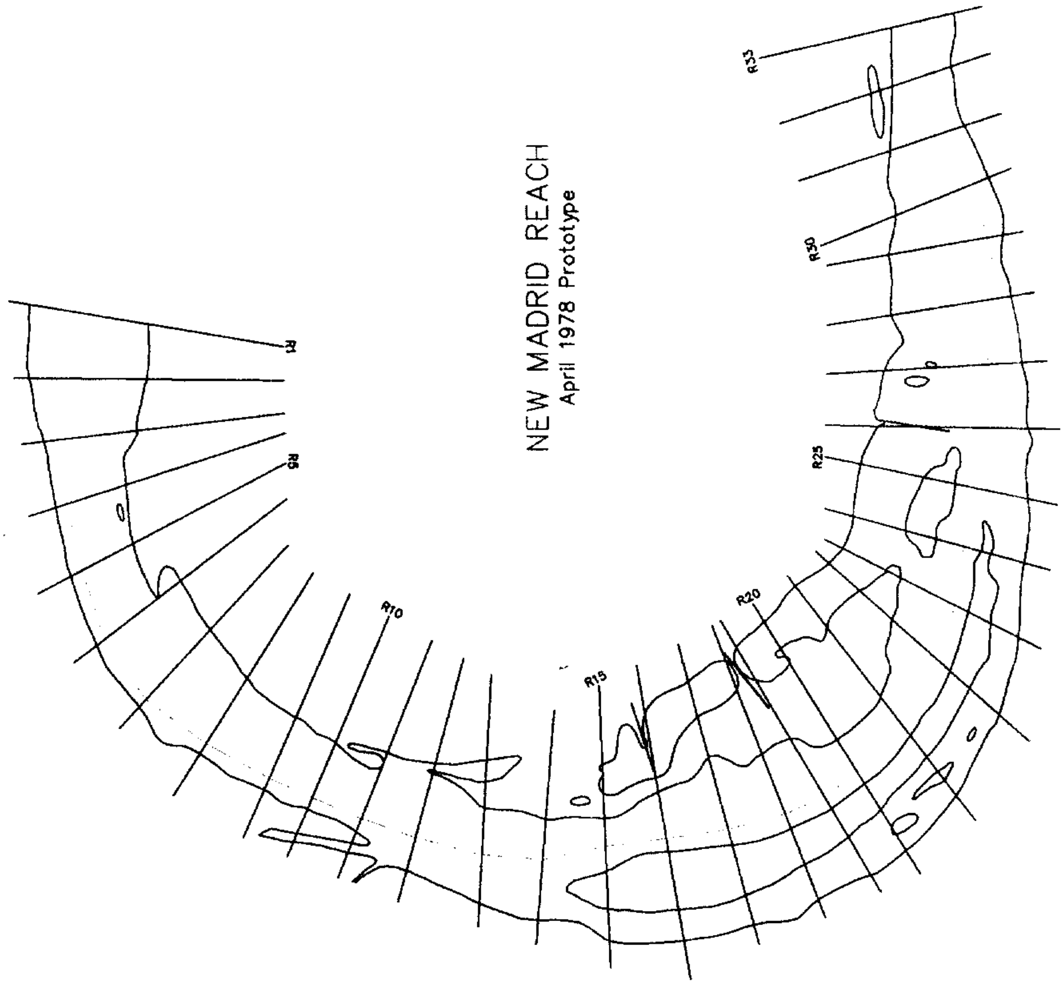

Figure B-12.1a New Madrid Model Plan View

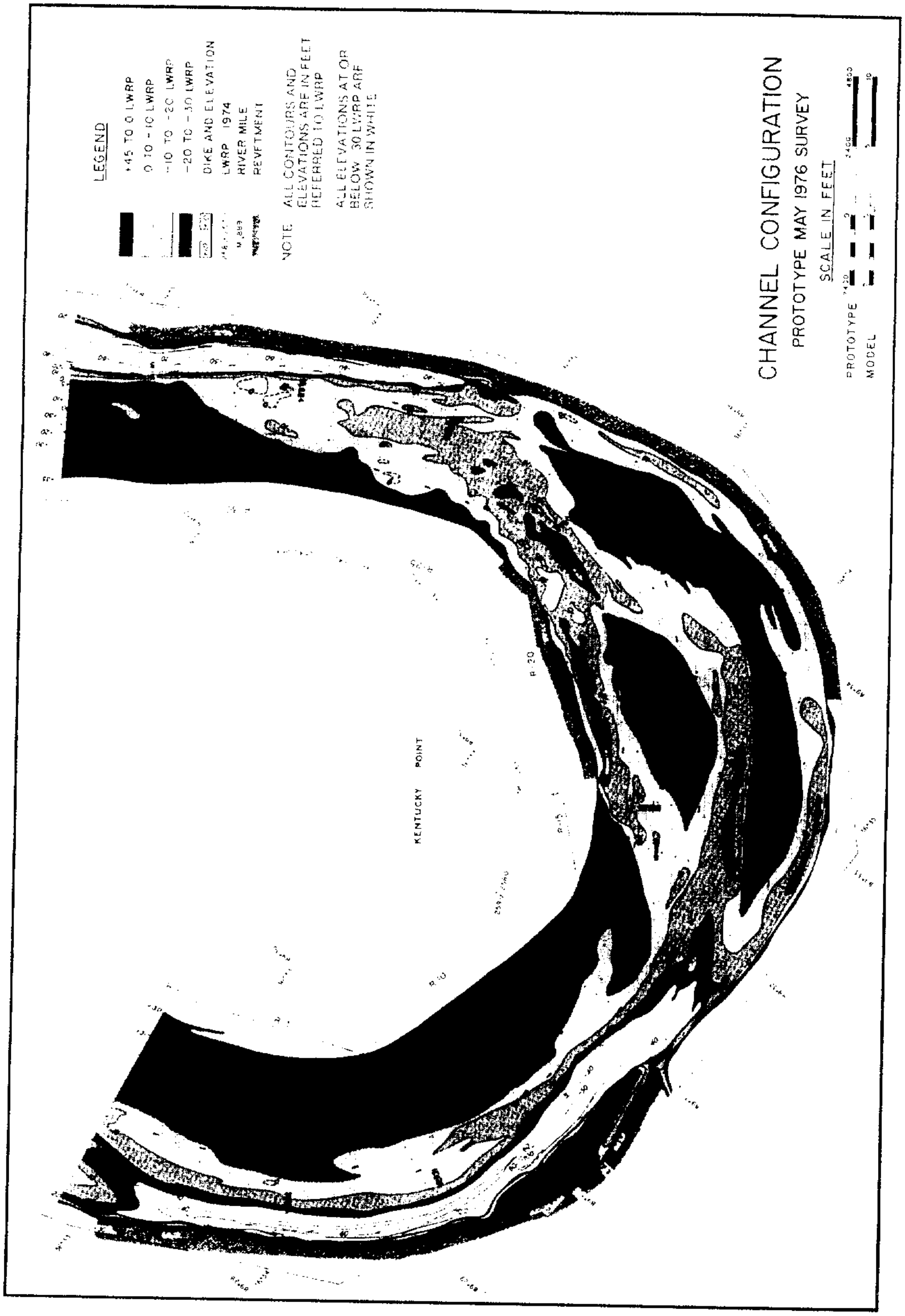

Figure B-12.1b New Madrid May 1976 Prototype Survey

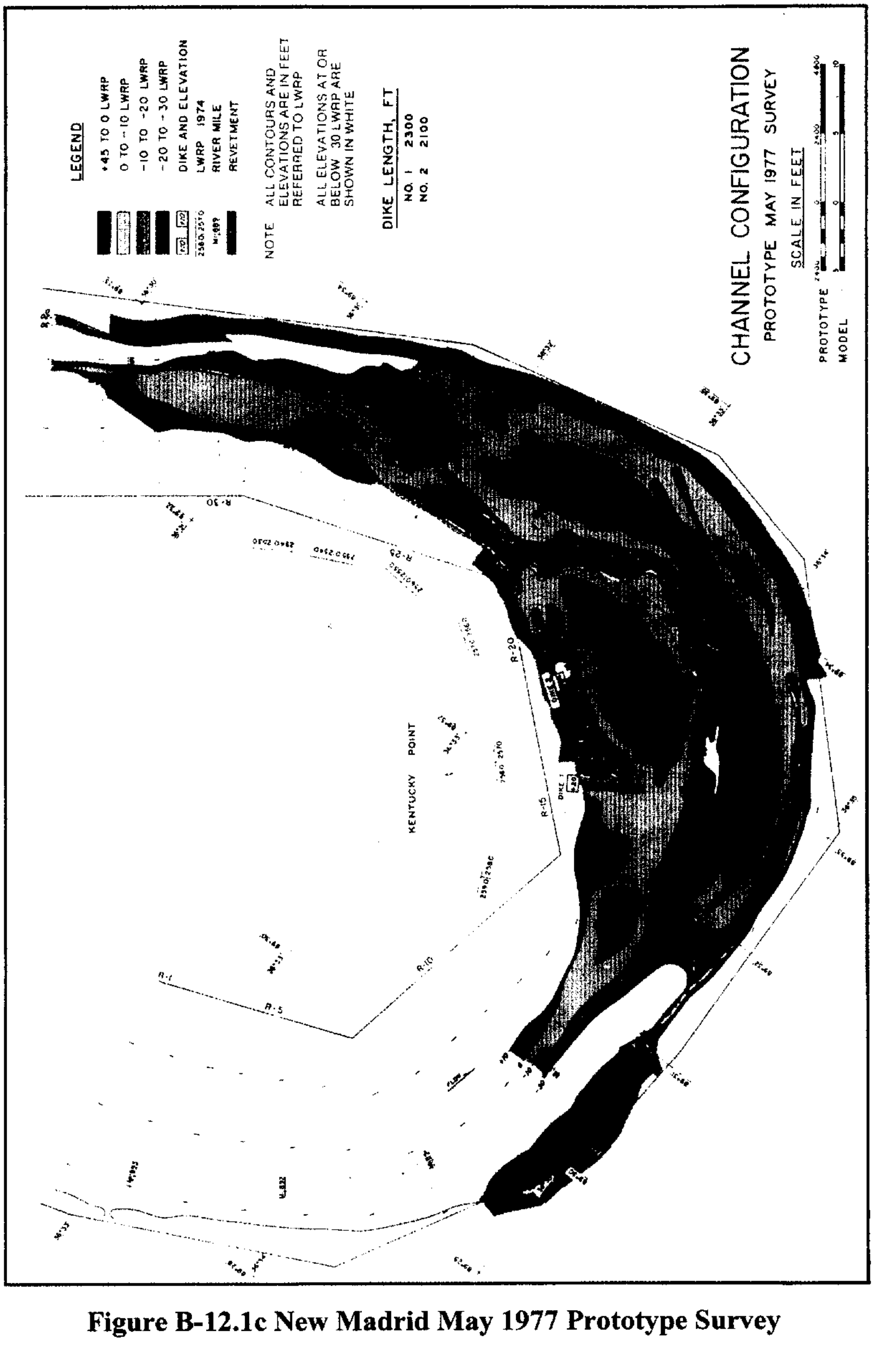

Figure B-12.1c New Madrid May 1977 Prototype Survey

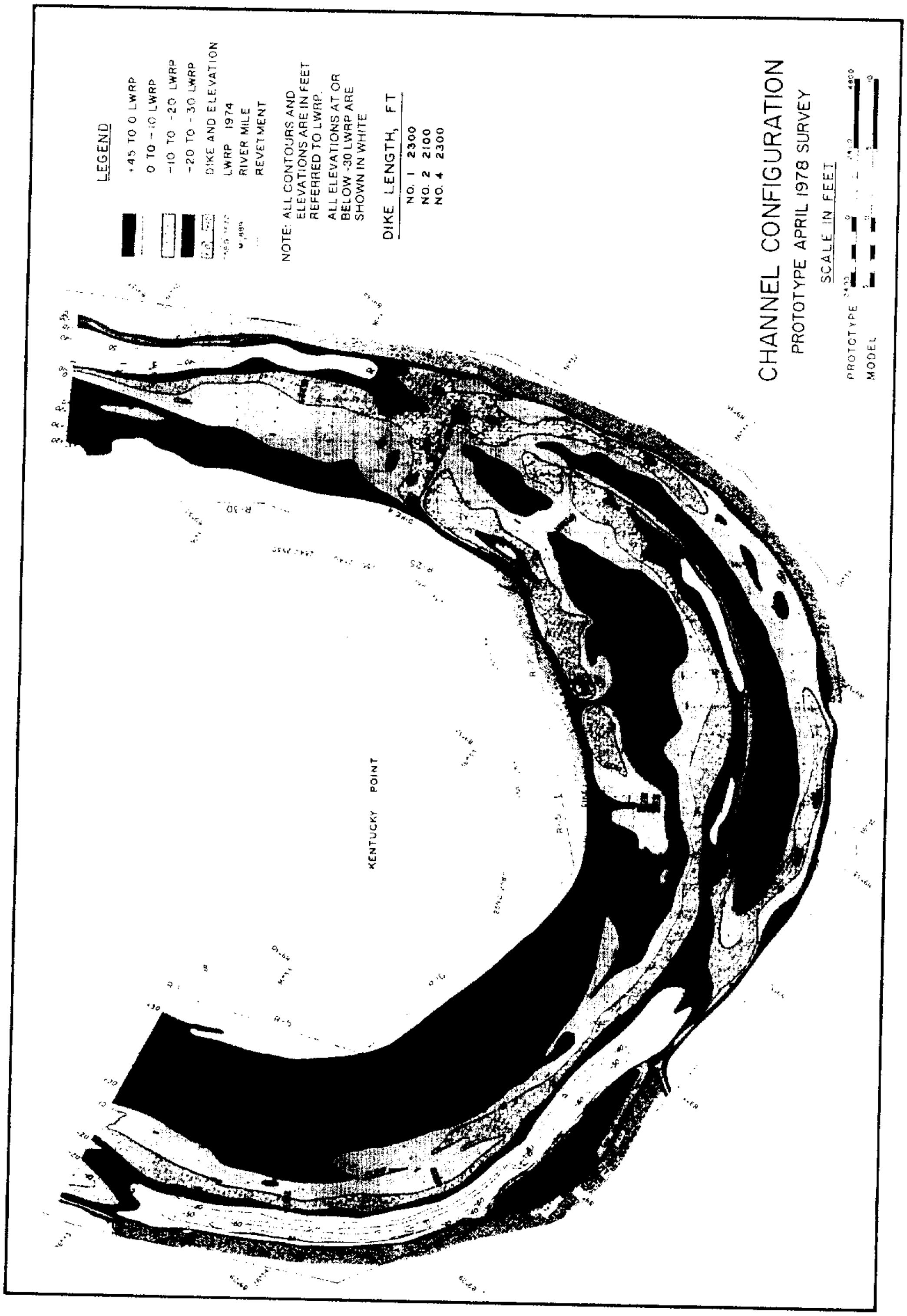

Figure B-12.1d New Madrid April 1978 Prototype Survey

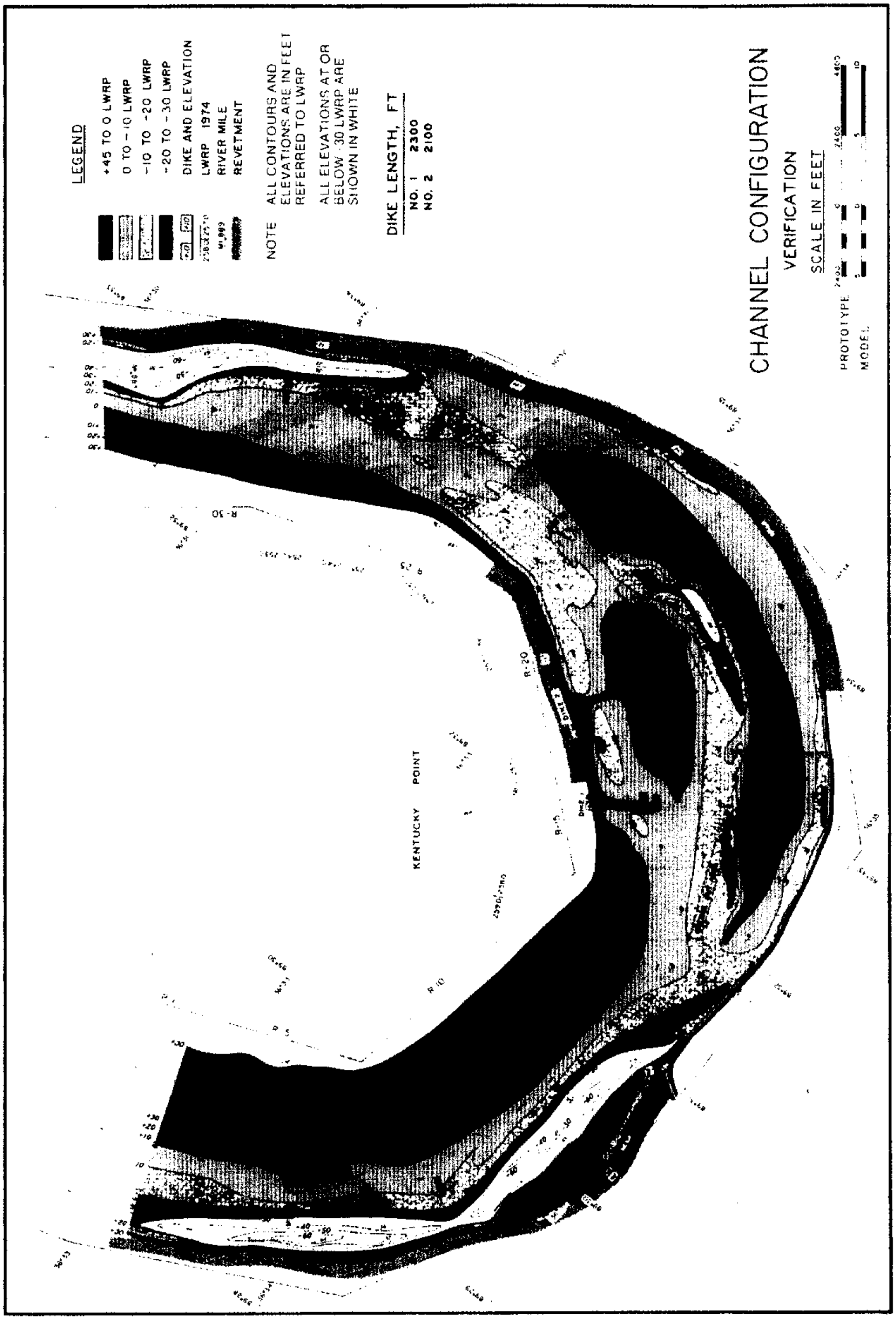

Figure B-12.1e New Madrid Verification Test Survey

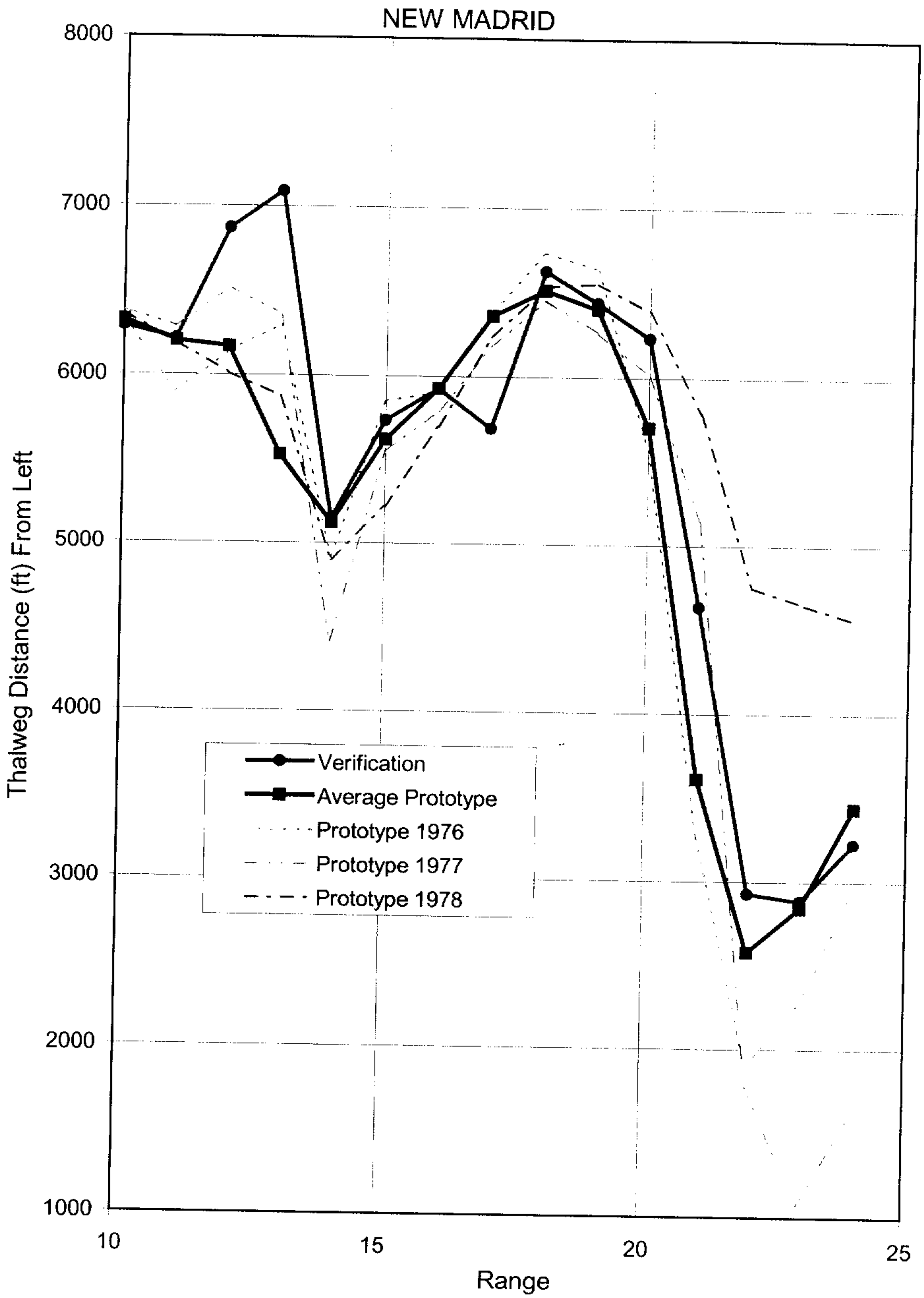

Figure B-12.2a Thalweg Position From Left by Range, New Madrid

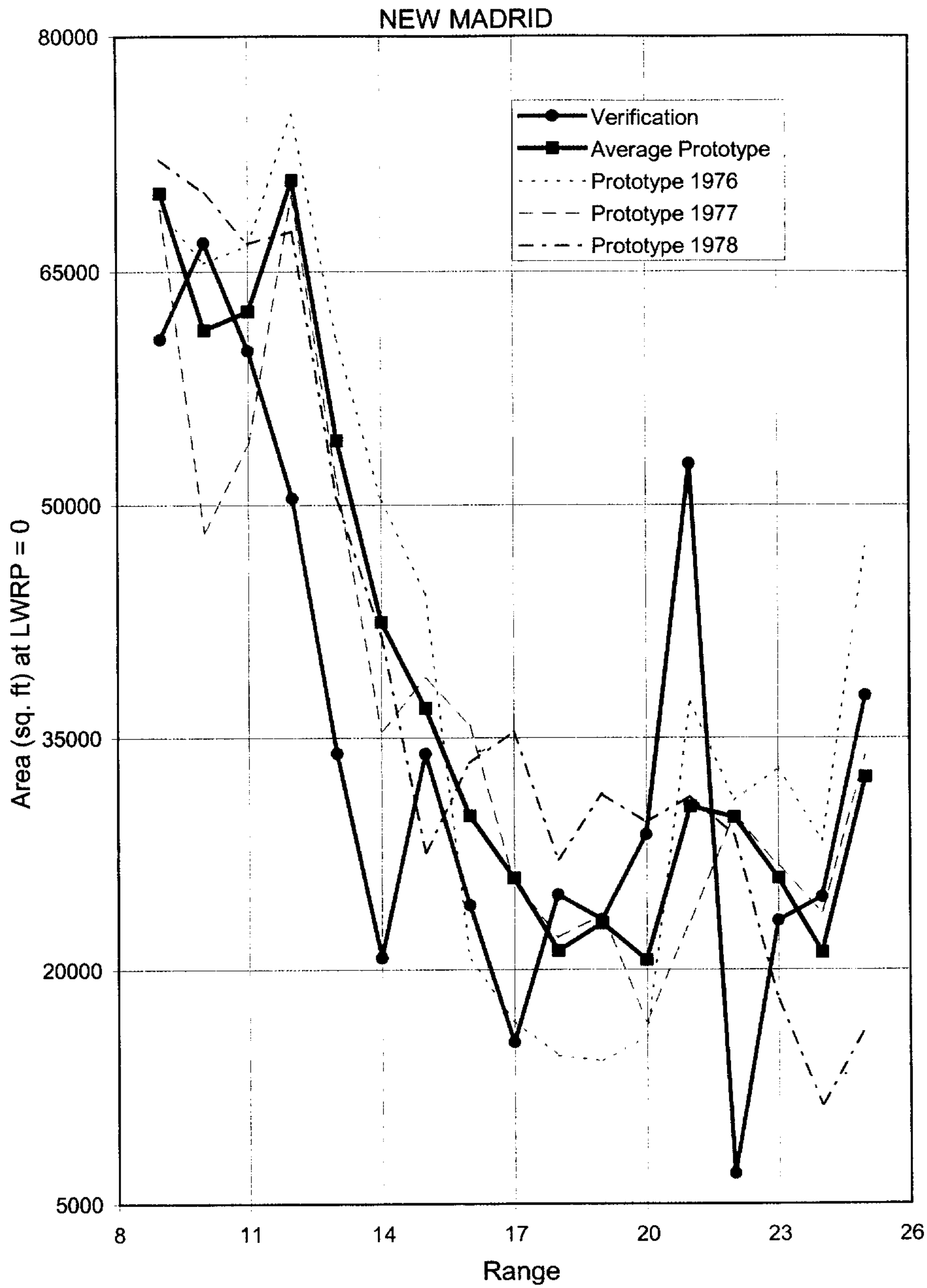

Figure B-12.2b Cross-Section Area by Range, New Madrid

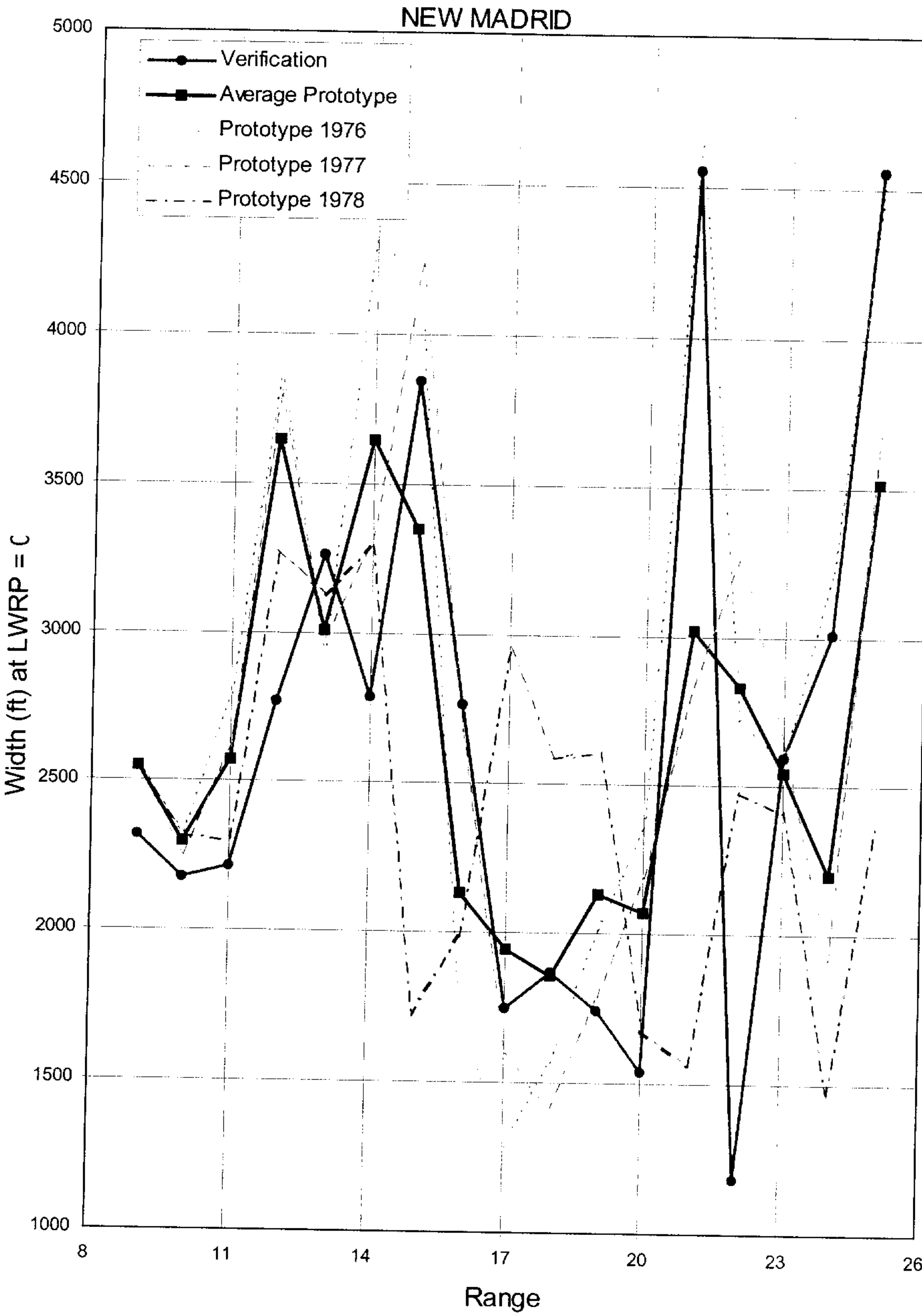

Figure B-12.2c Top Width by Range, New Madrid

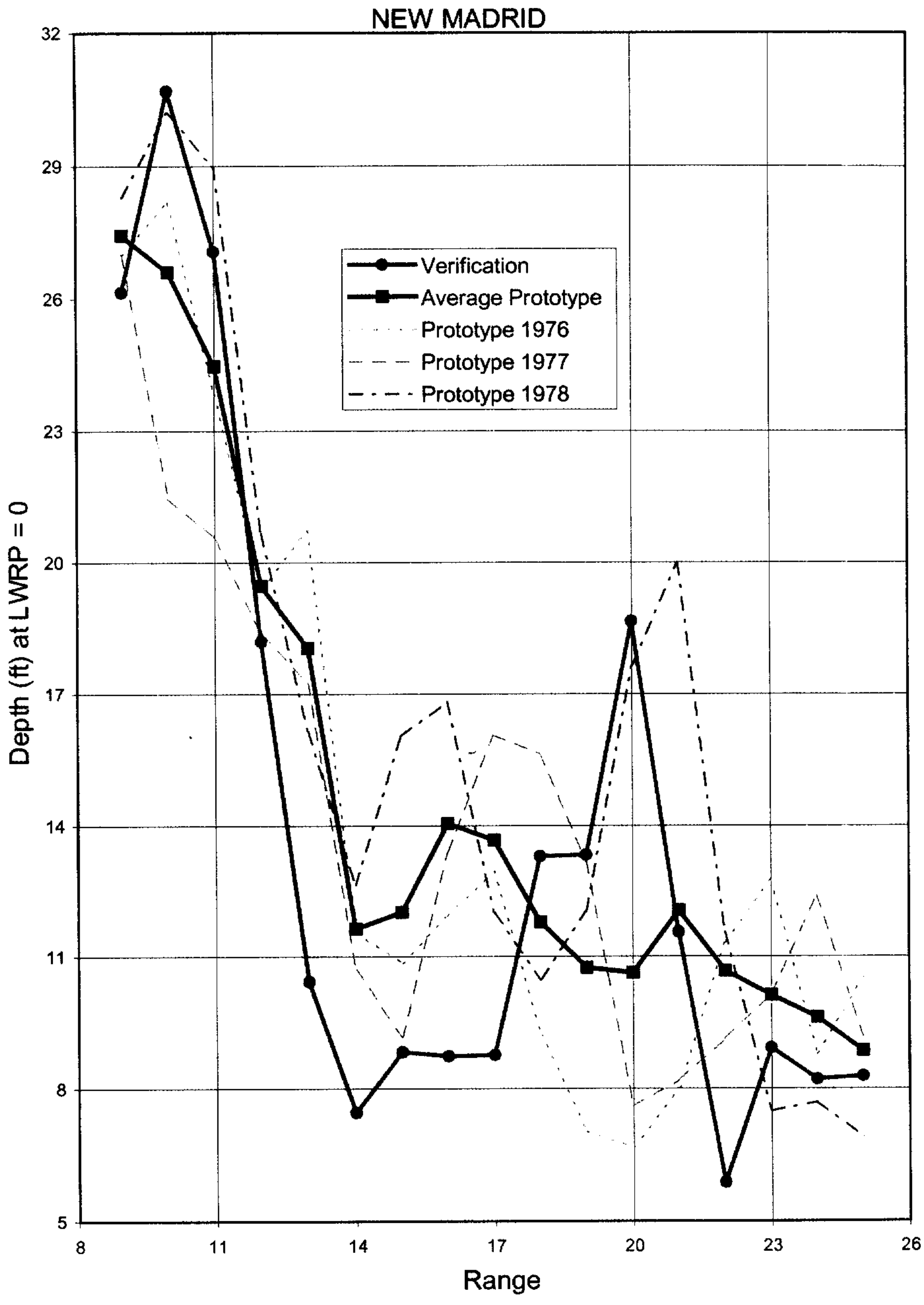

Figure B-12.2d Hydraulic Depth by Range, New Madrid

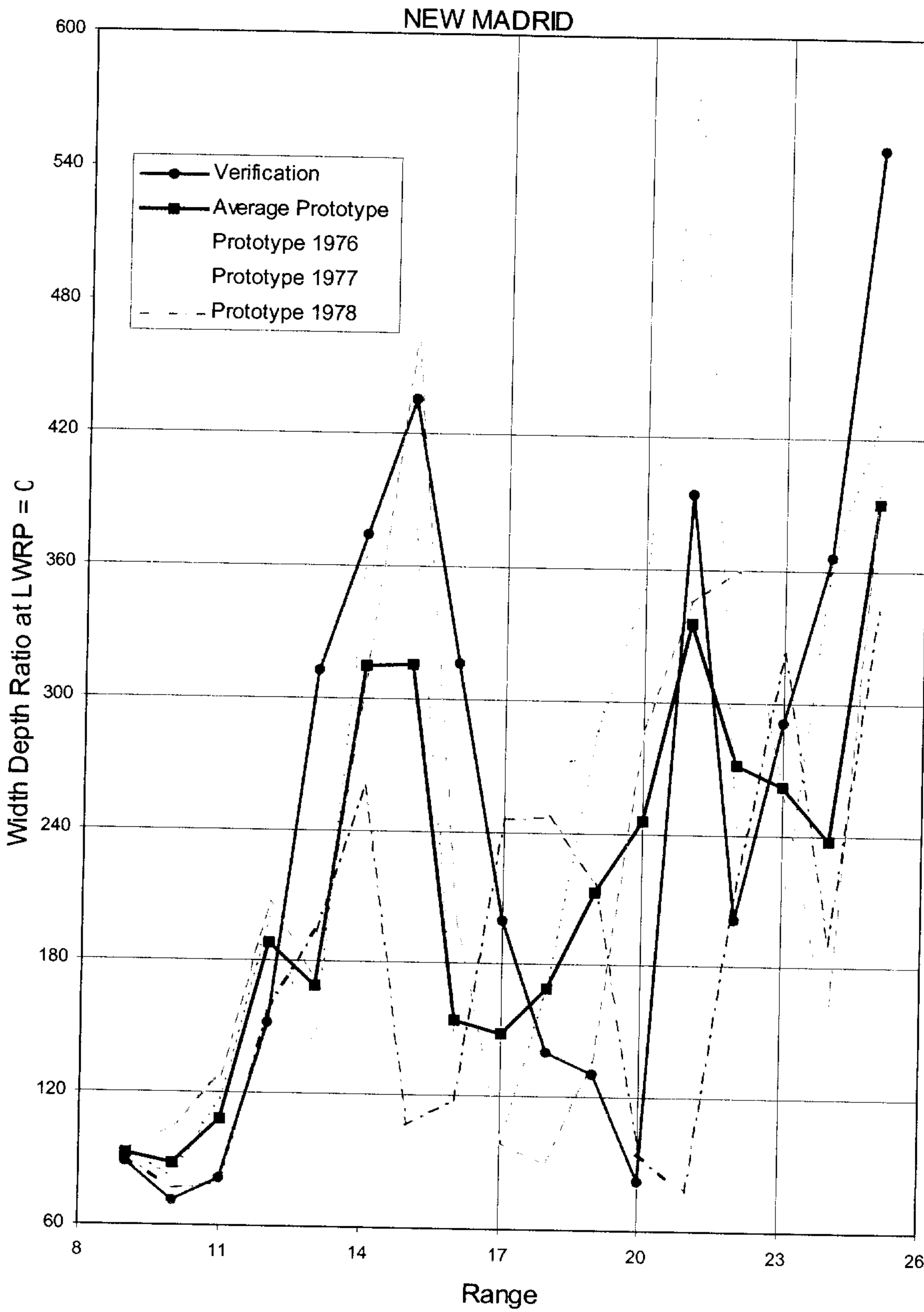

Figure B-12.2e Width/Depth Ratio by Range, New Madrid

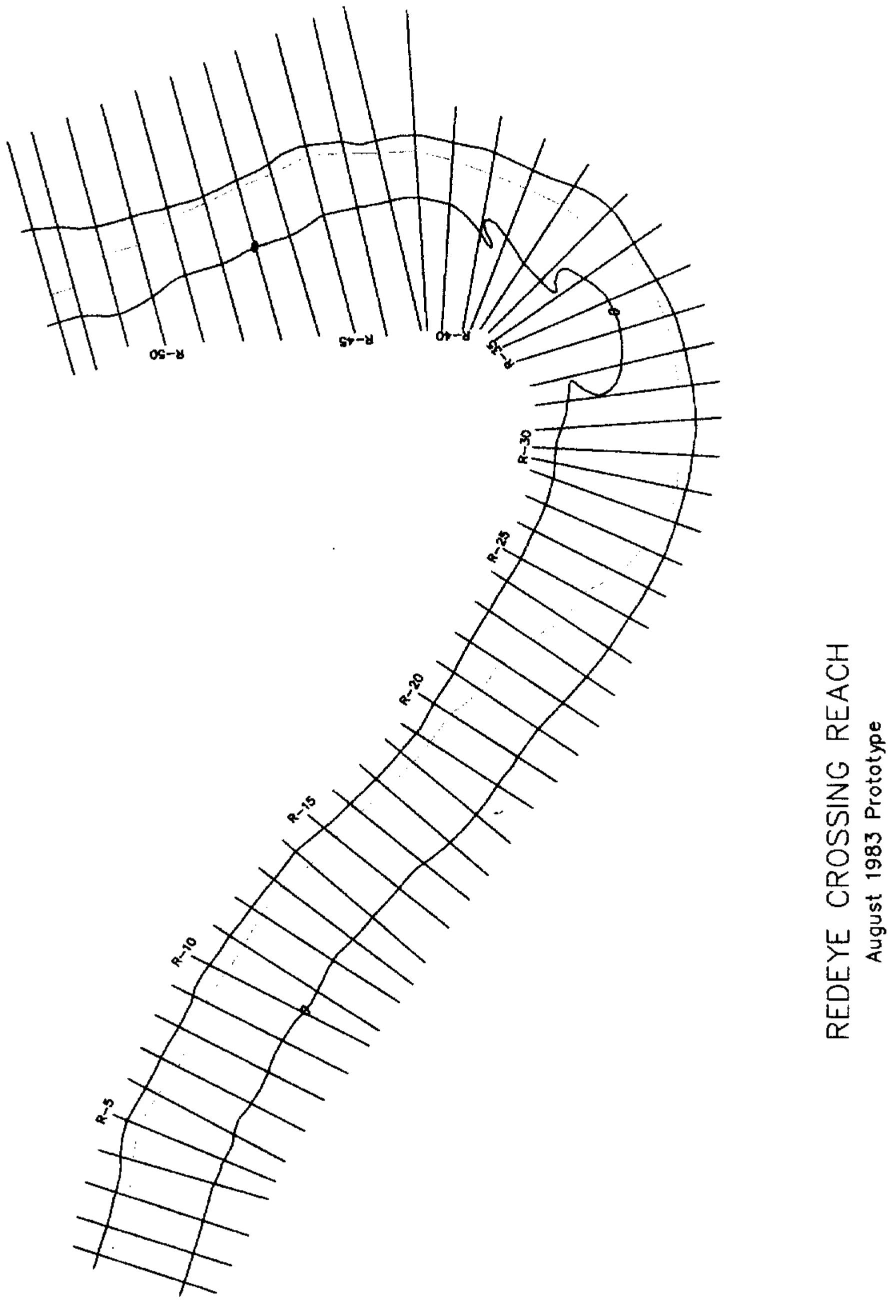

Figure B-13.1a Redeye Crossing Model Plan View

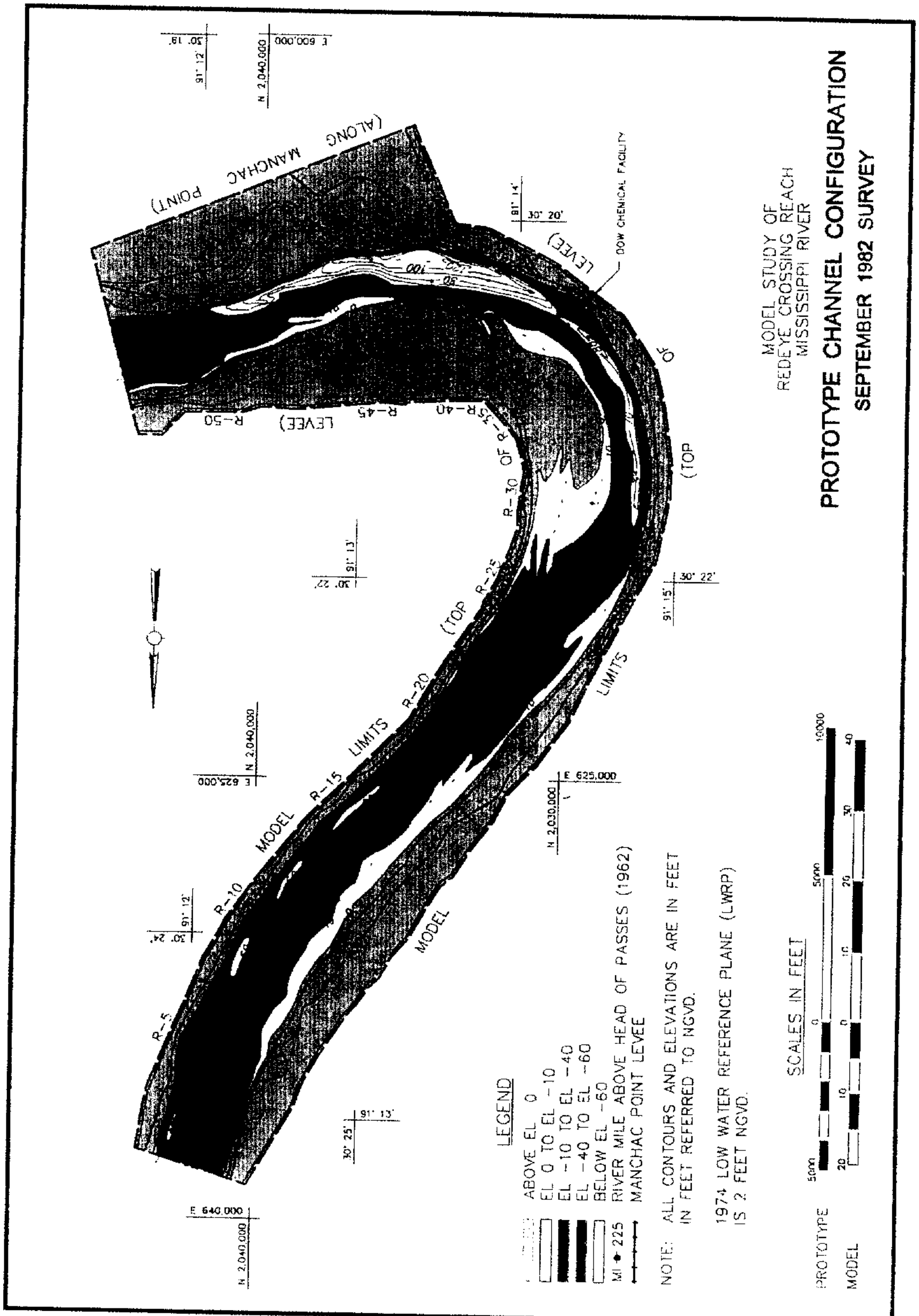

Figure B-13.1b 1982 Prototype Survey, Redeye Crossing

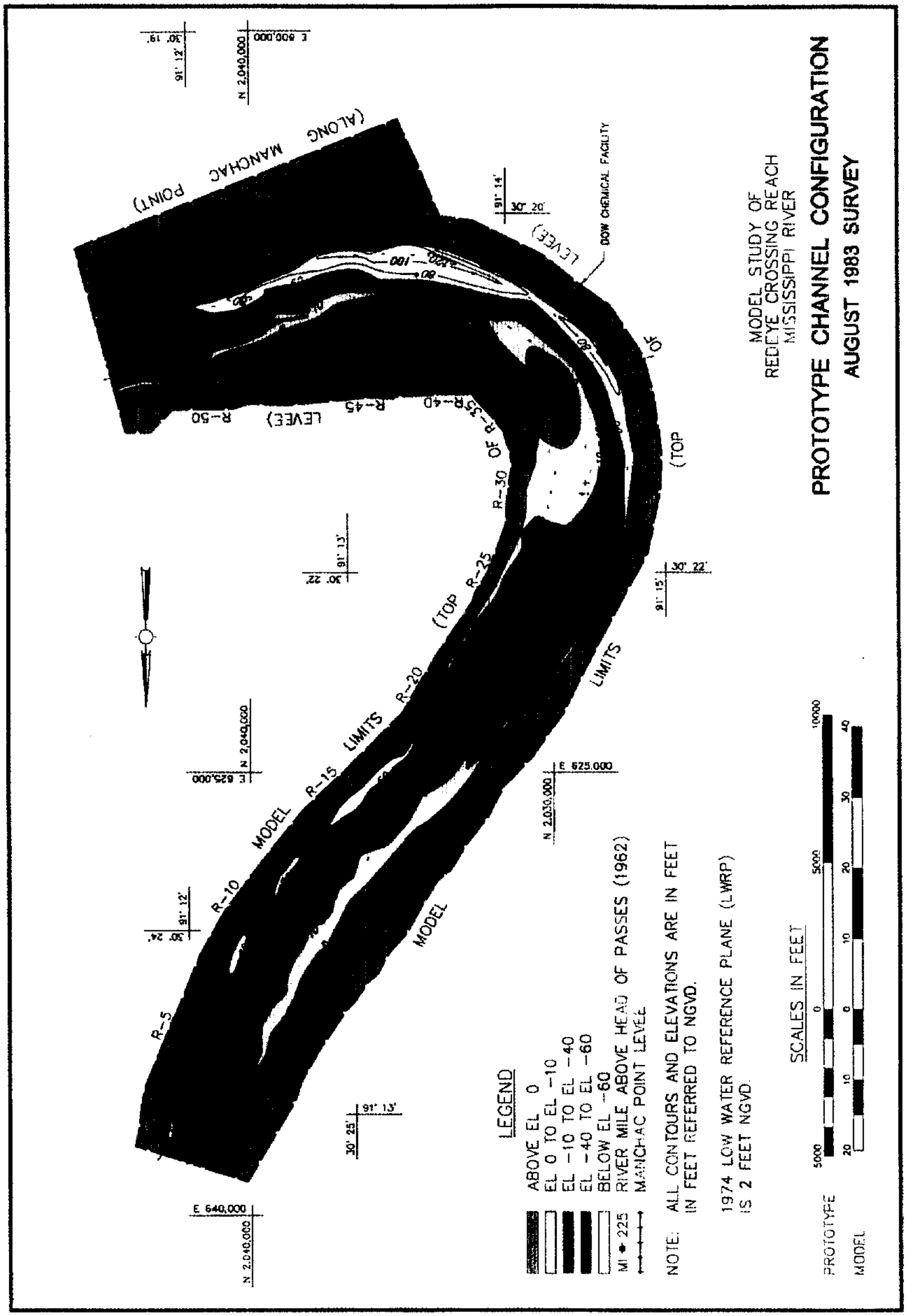

Figure B-13.1c 1983 Prototype Survey, Redeye Crossing

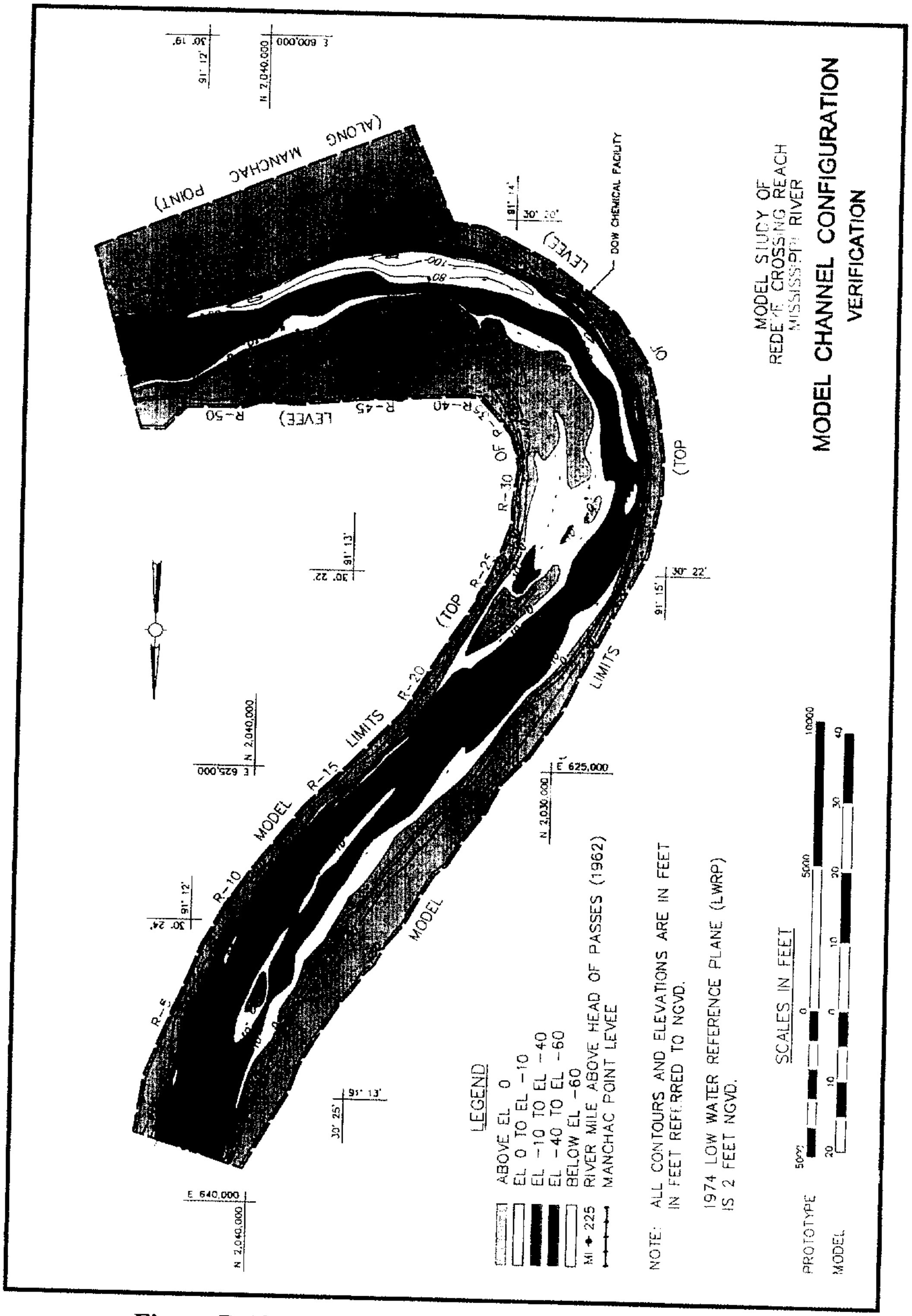

Figure B-13.1d Verification Survey, Redeye Crossing

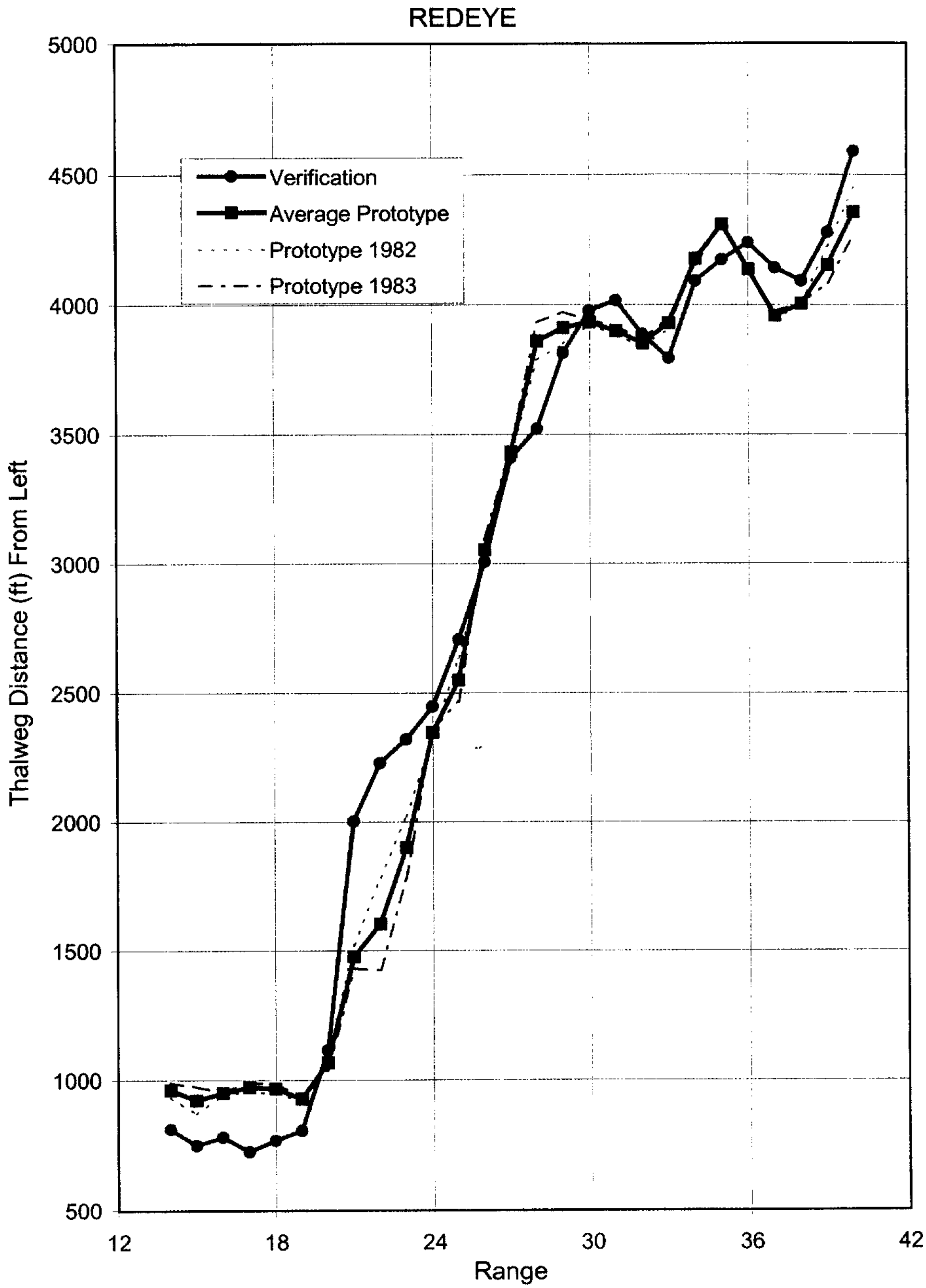

Figure B-13.2a Thalweg Location From Left by Range, Redeye Crossing

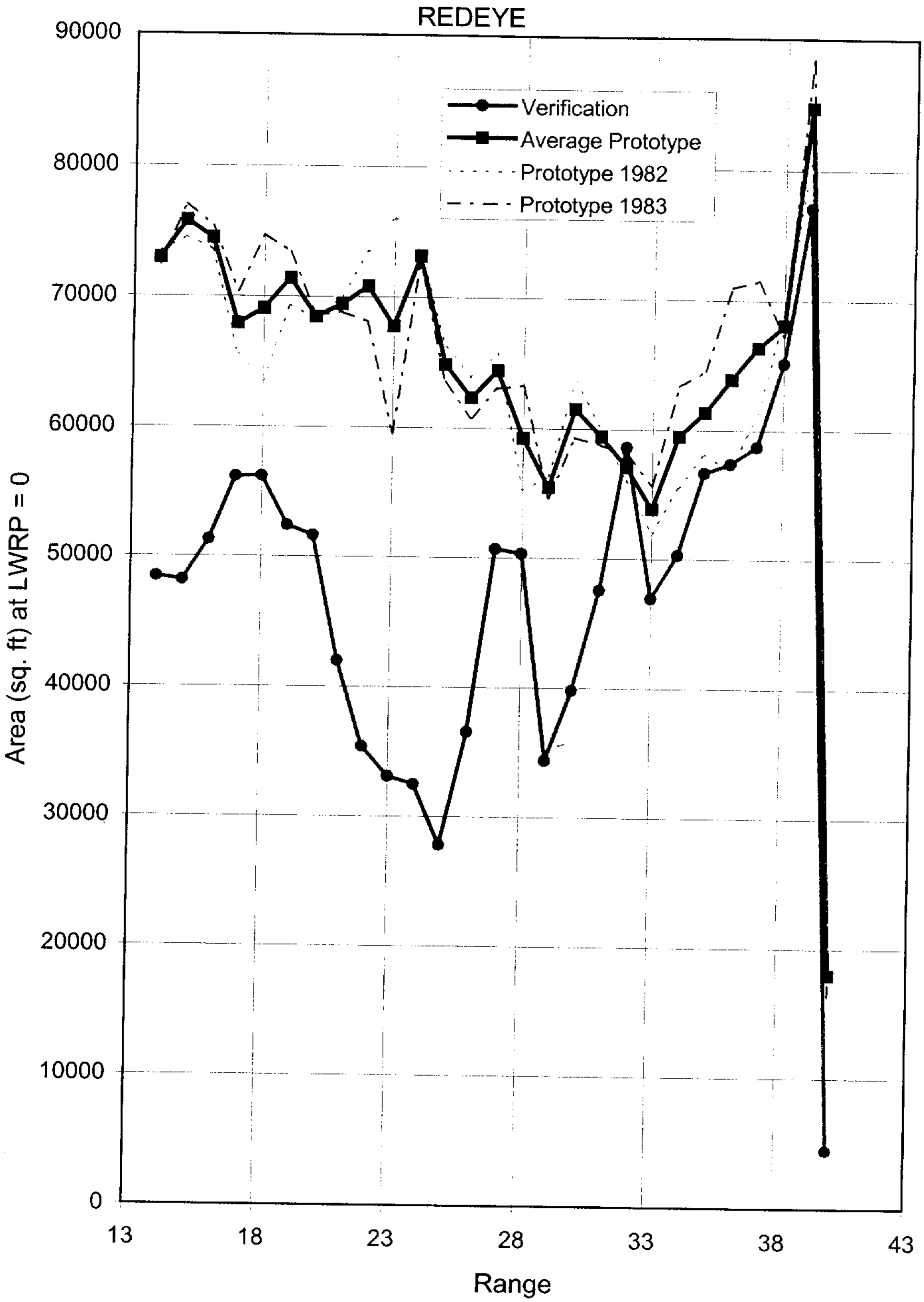

Figure B-13.2b Cross-Section Area by Range, Redeye Crossing

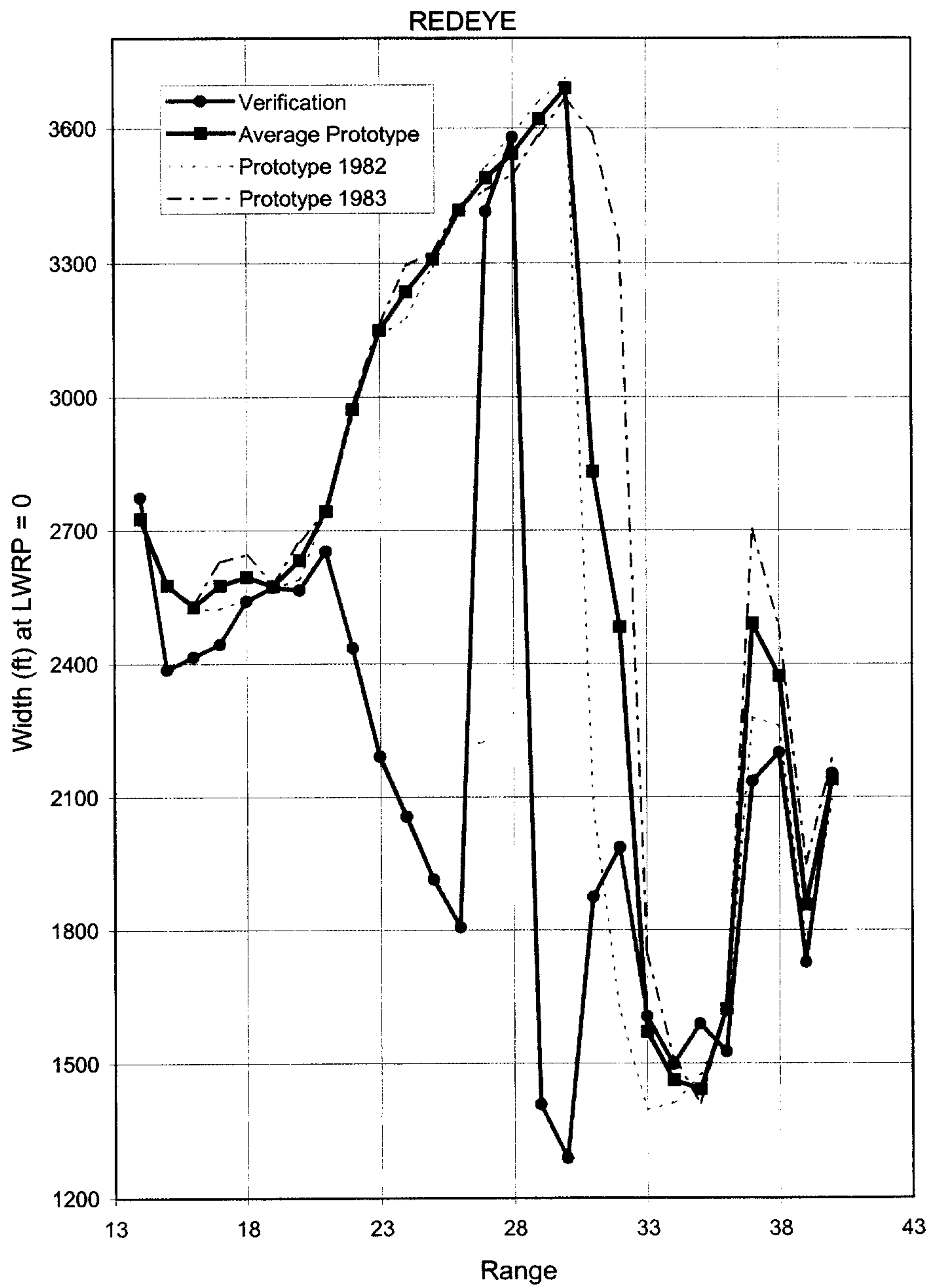

Figure B-13.2c Top Width by Range, Redeye Crossing

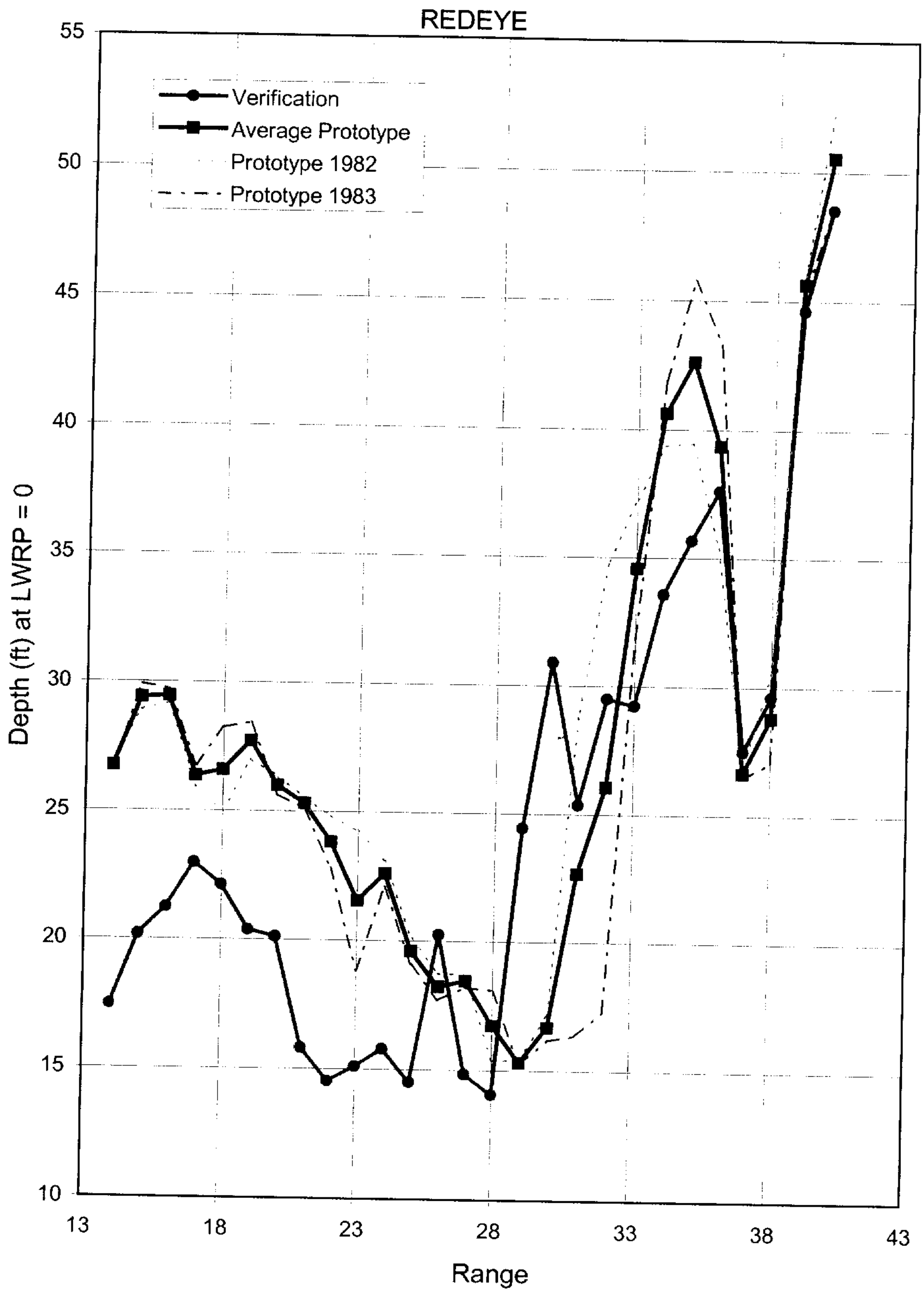

Figure B-13.2d Hydraulic Depth by Range, Redeye Crossing

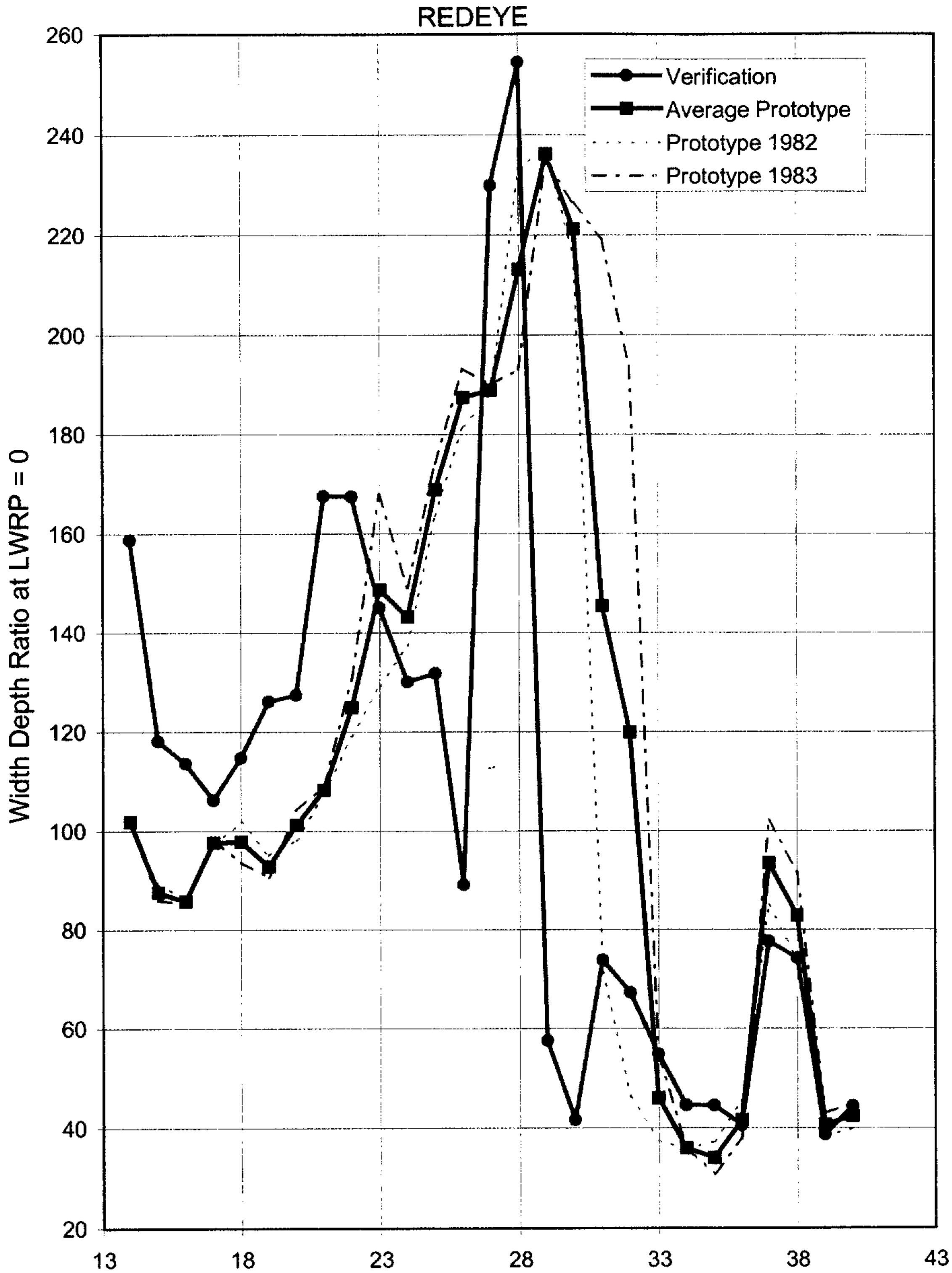

Figure B-13.2e Width/Depth Ratio by Range, Redeye Crossing

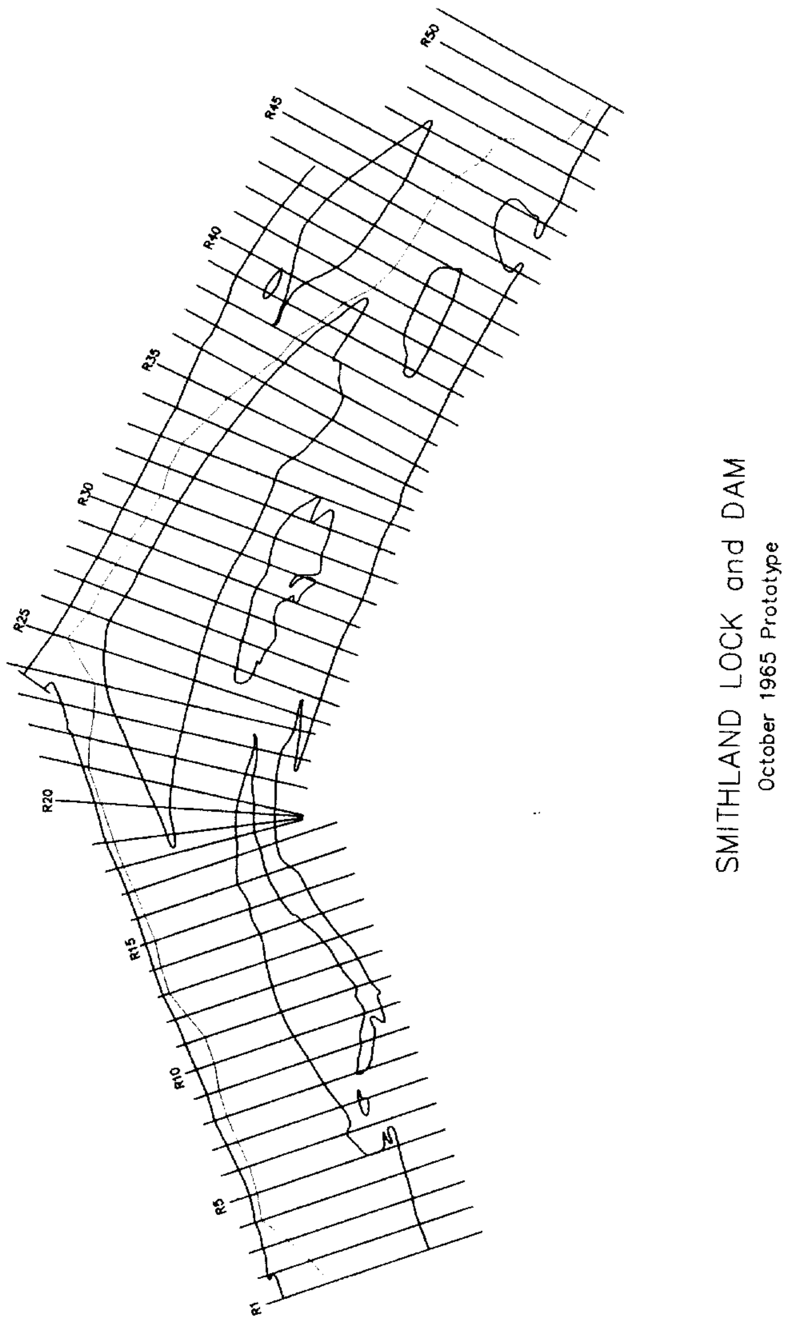

Figure B-14.1a Smithland Lock Model Plan View

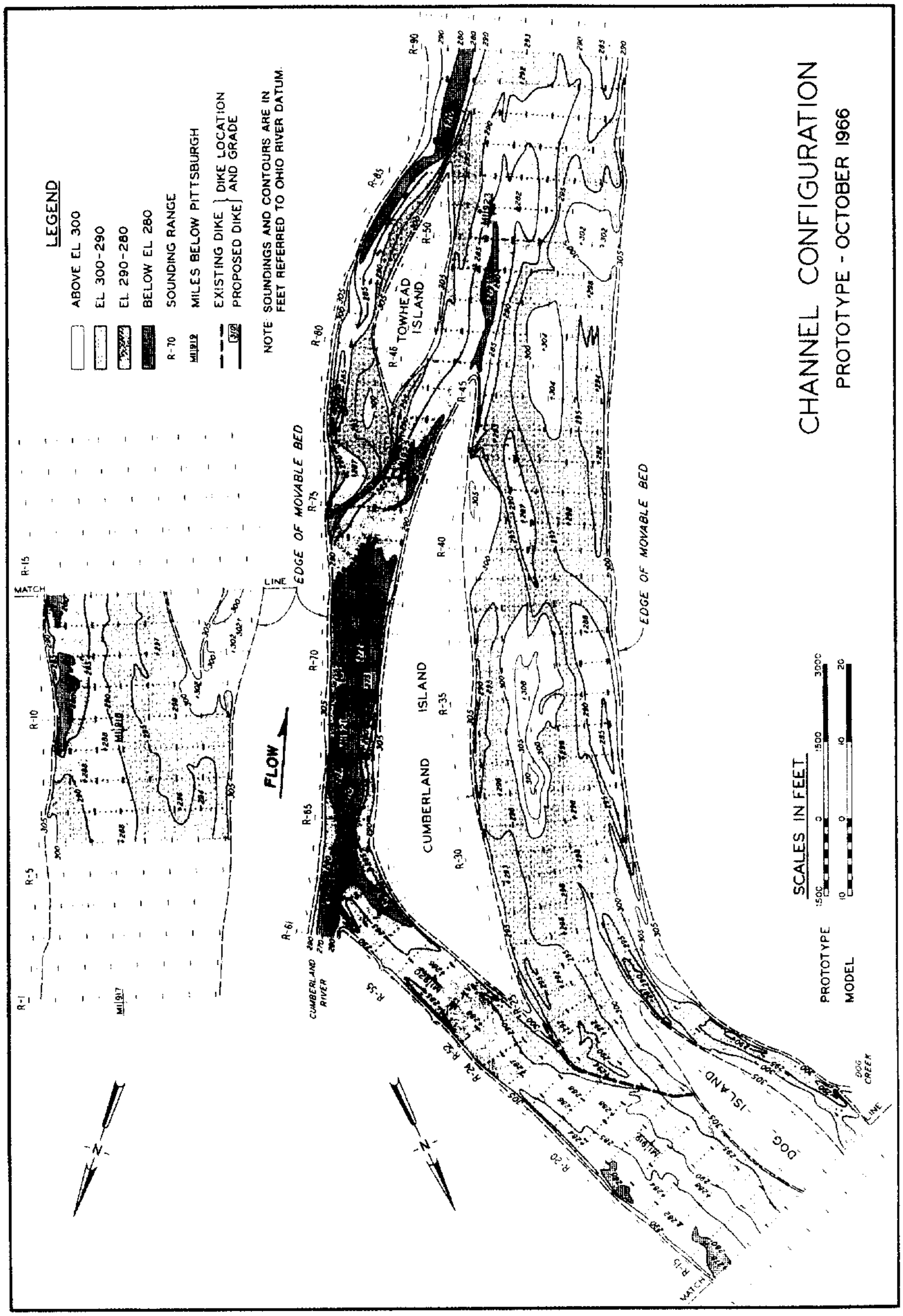

Figure B-14.1b Smithland Lock October 1966 Prototype Survey

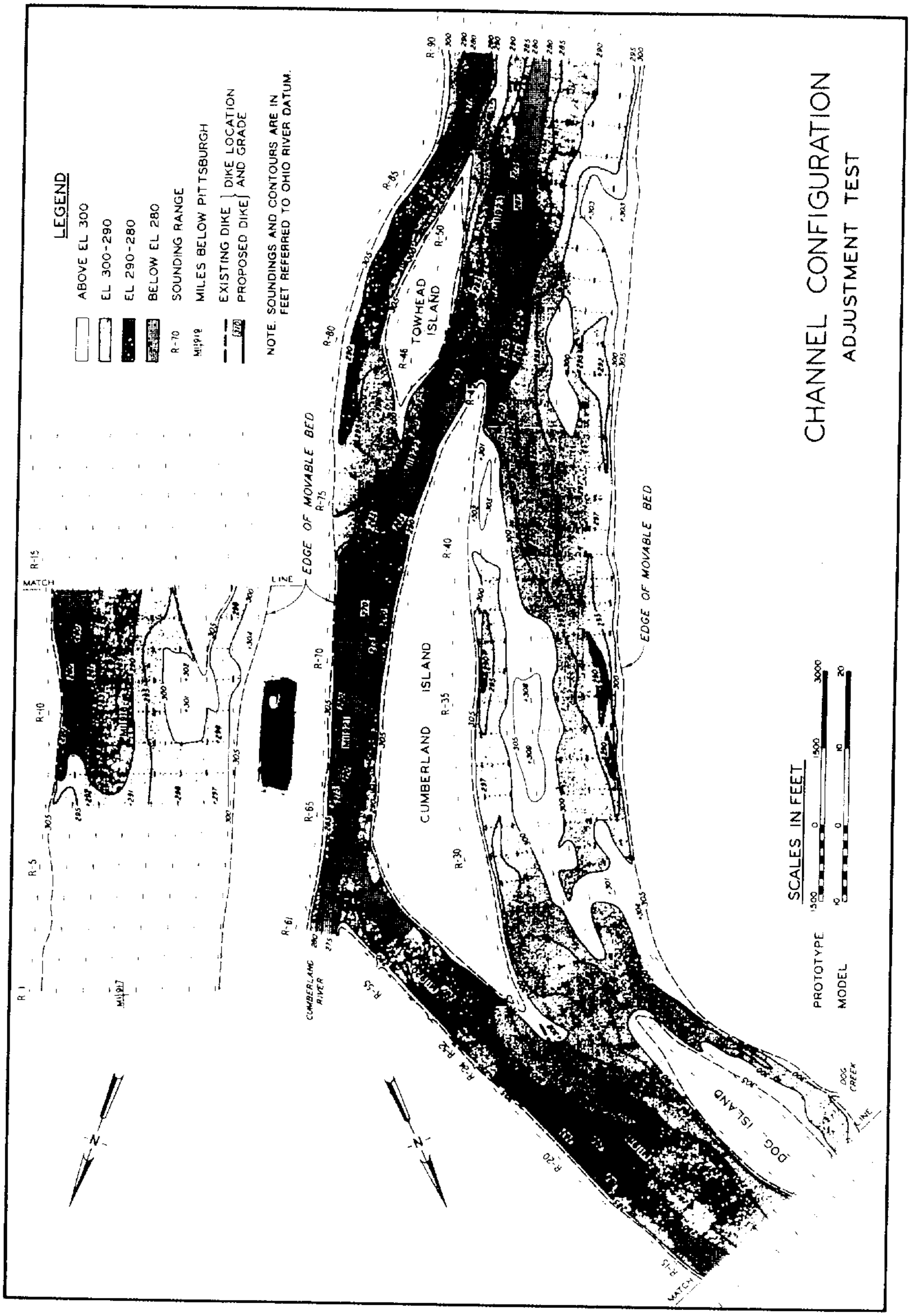

Figure B-14.1c Smithland Lock Verification Test Survey

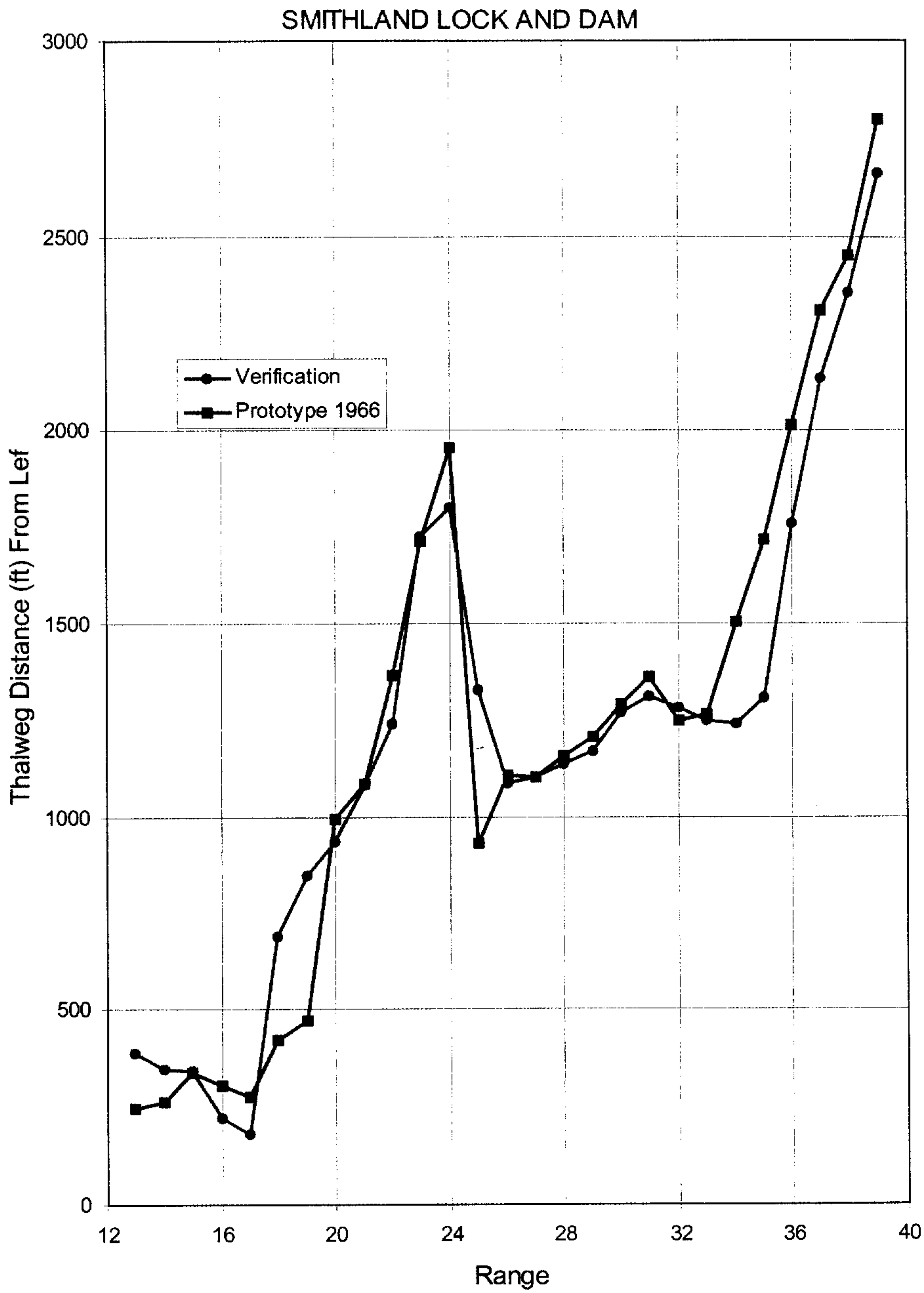

Figure B-14.2a Thalweg Location From Left by Range, Smithland Lock and Dam

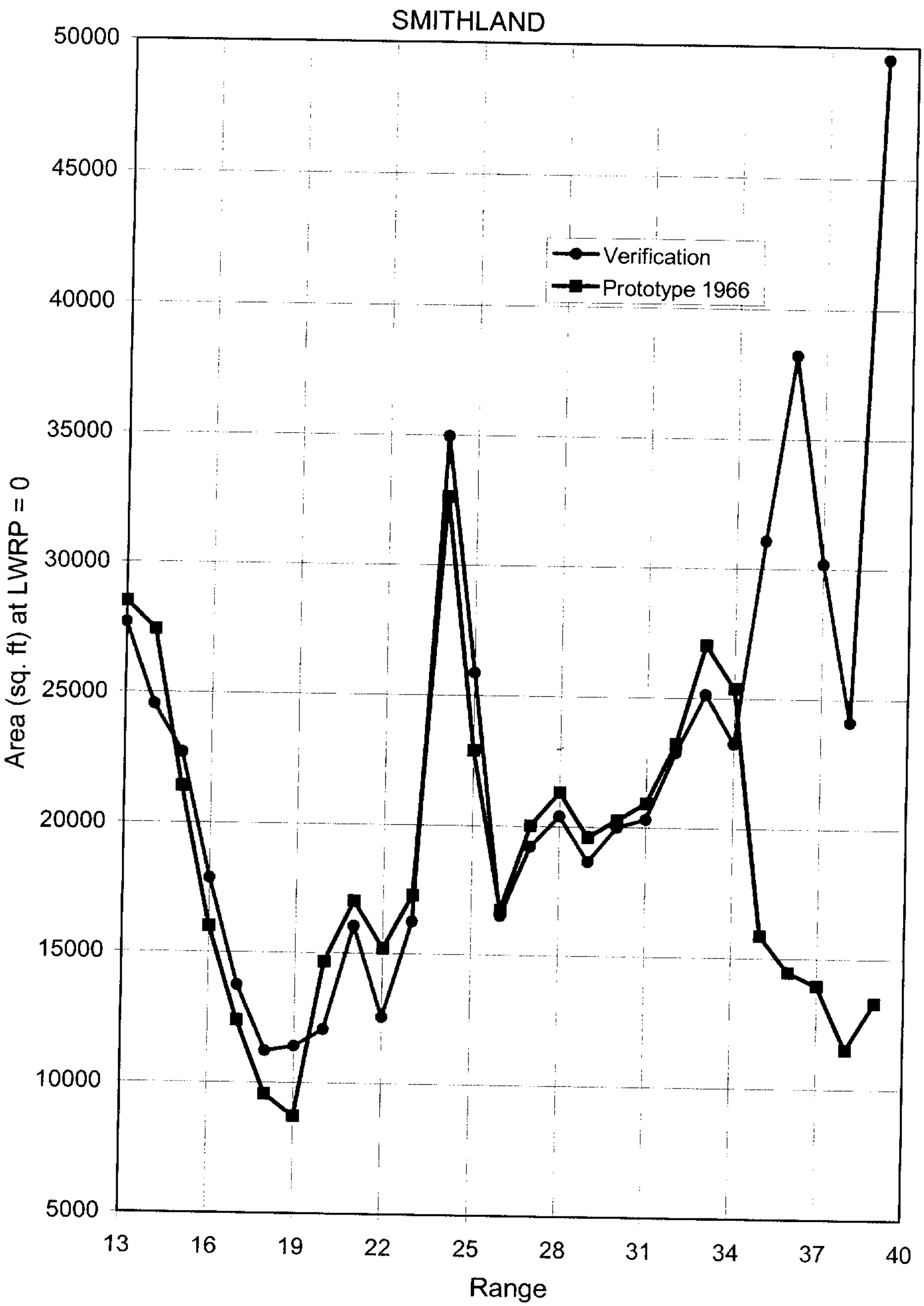

Figure B-14.2b Cross-Section Area by Range, Smithland Lock and Dam

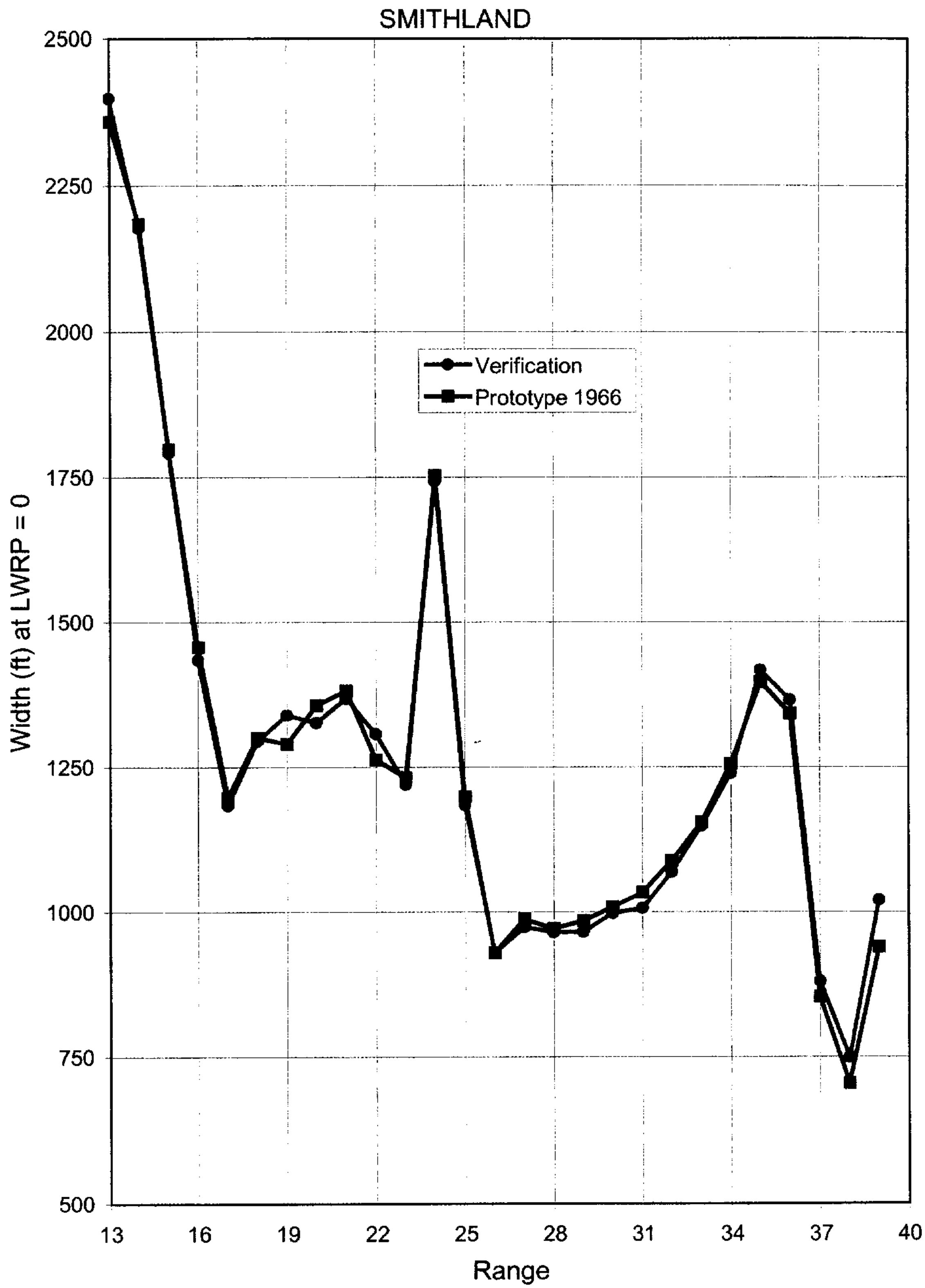

Figure B-14.2c Top Width by Range, Smithland Lock and Dam

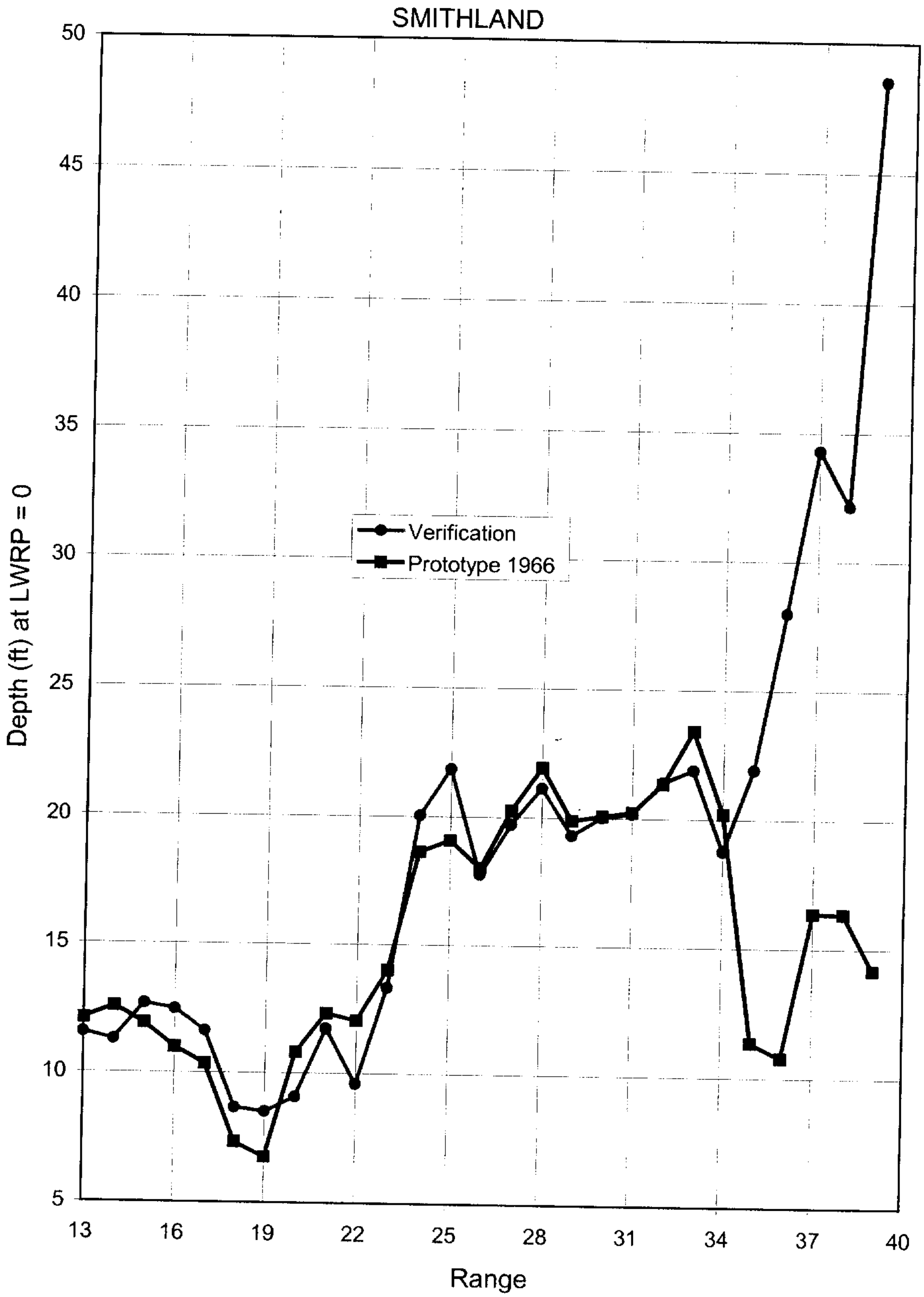

Figure B-14.2d Hydraulic Depth by Range, Smithland Lock and Dam

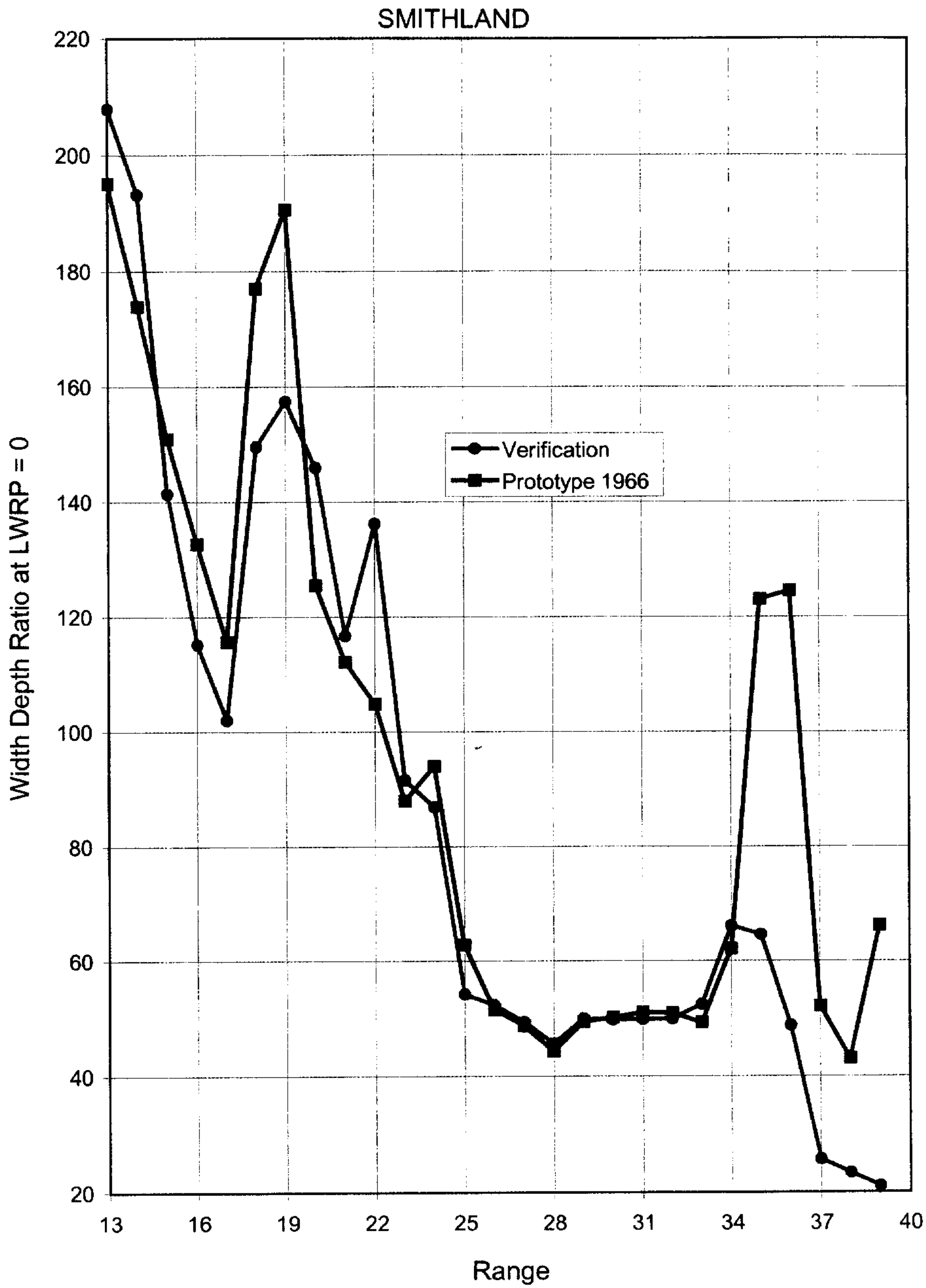

Figure B-14.2e Width/Depth Ratio by Range, Smithland Lock and Dam

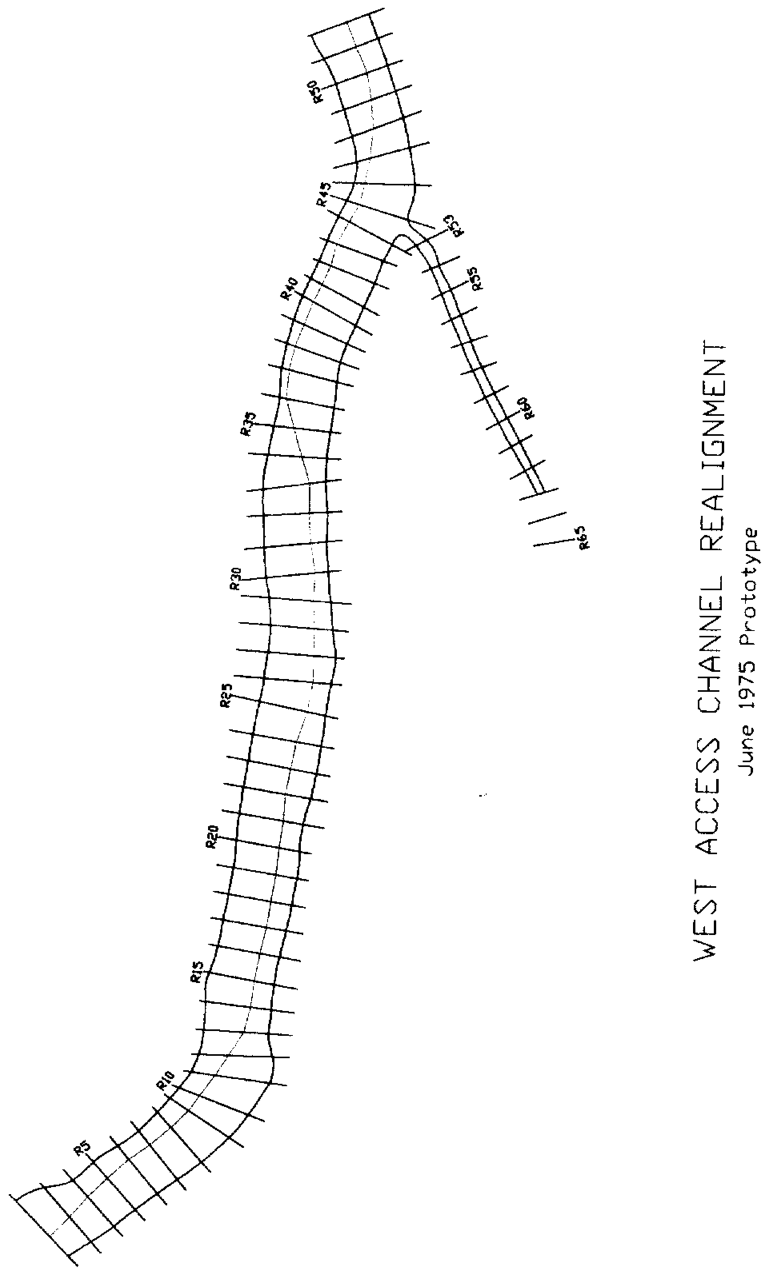

Figure B-15.1a West Access Channel Model Plan View

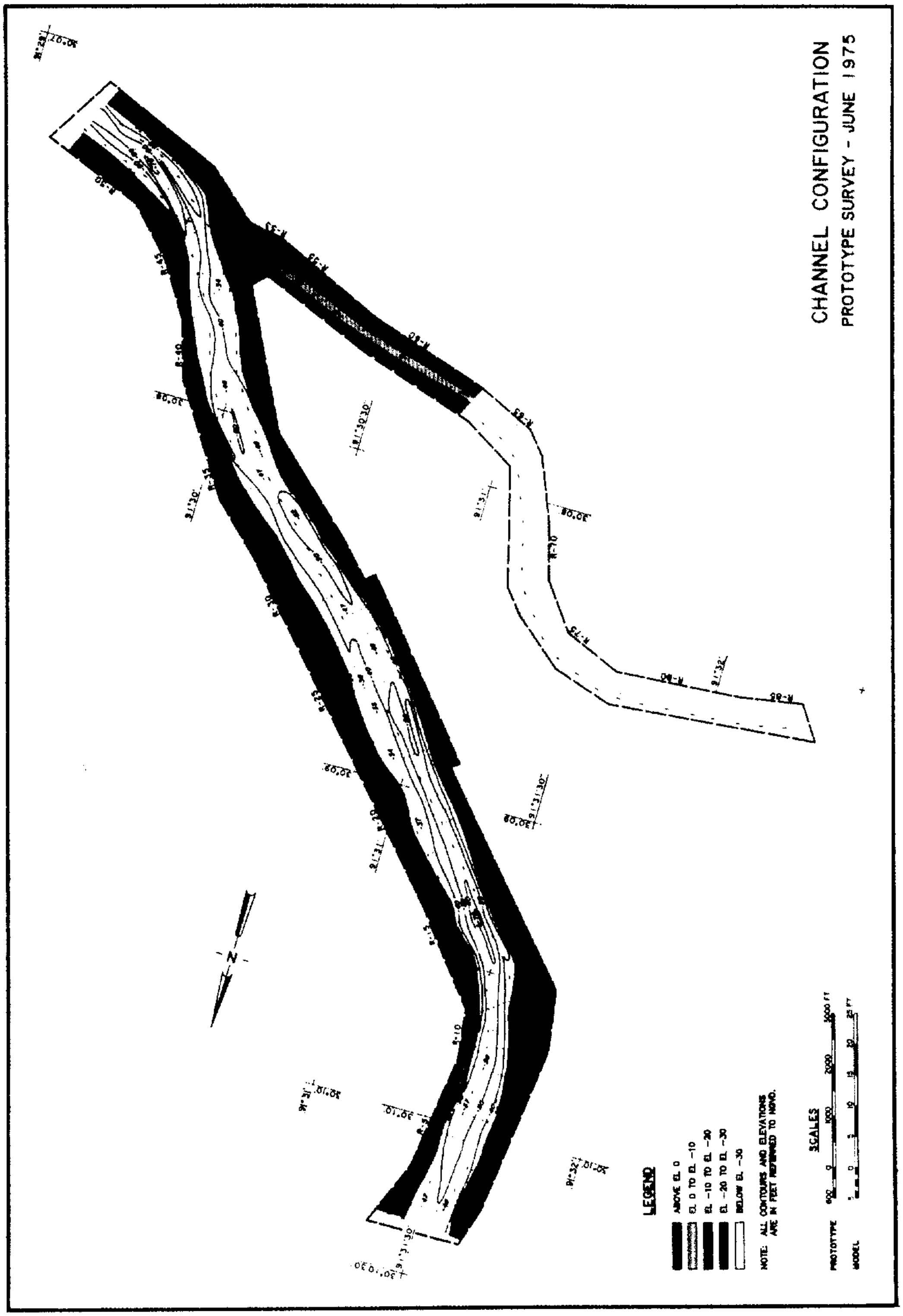

Figure B-15.1b West Access Channel 1975 Prototype Survey

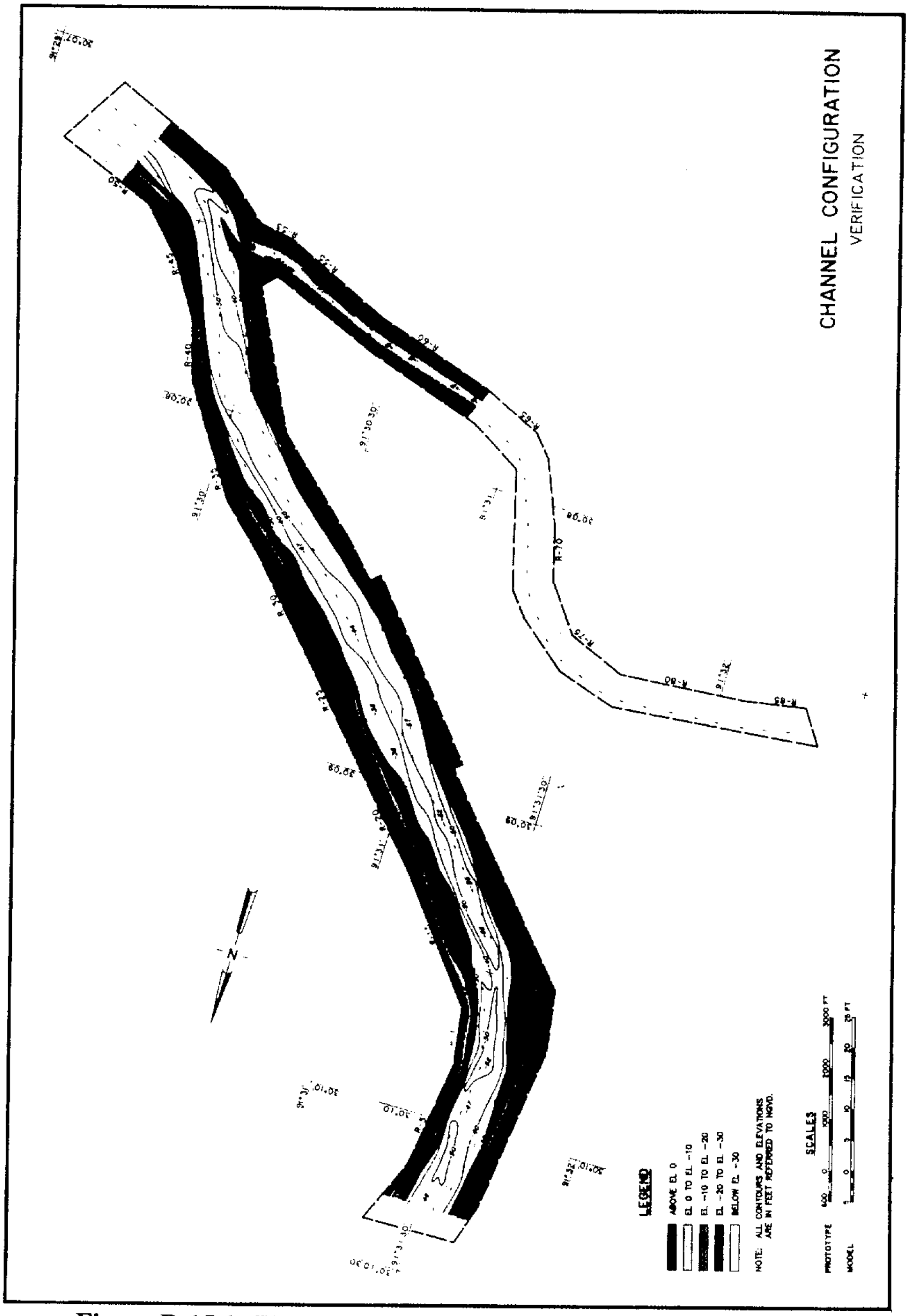

Figure B-15.1c West Access Channel Verification Test Survey

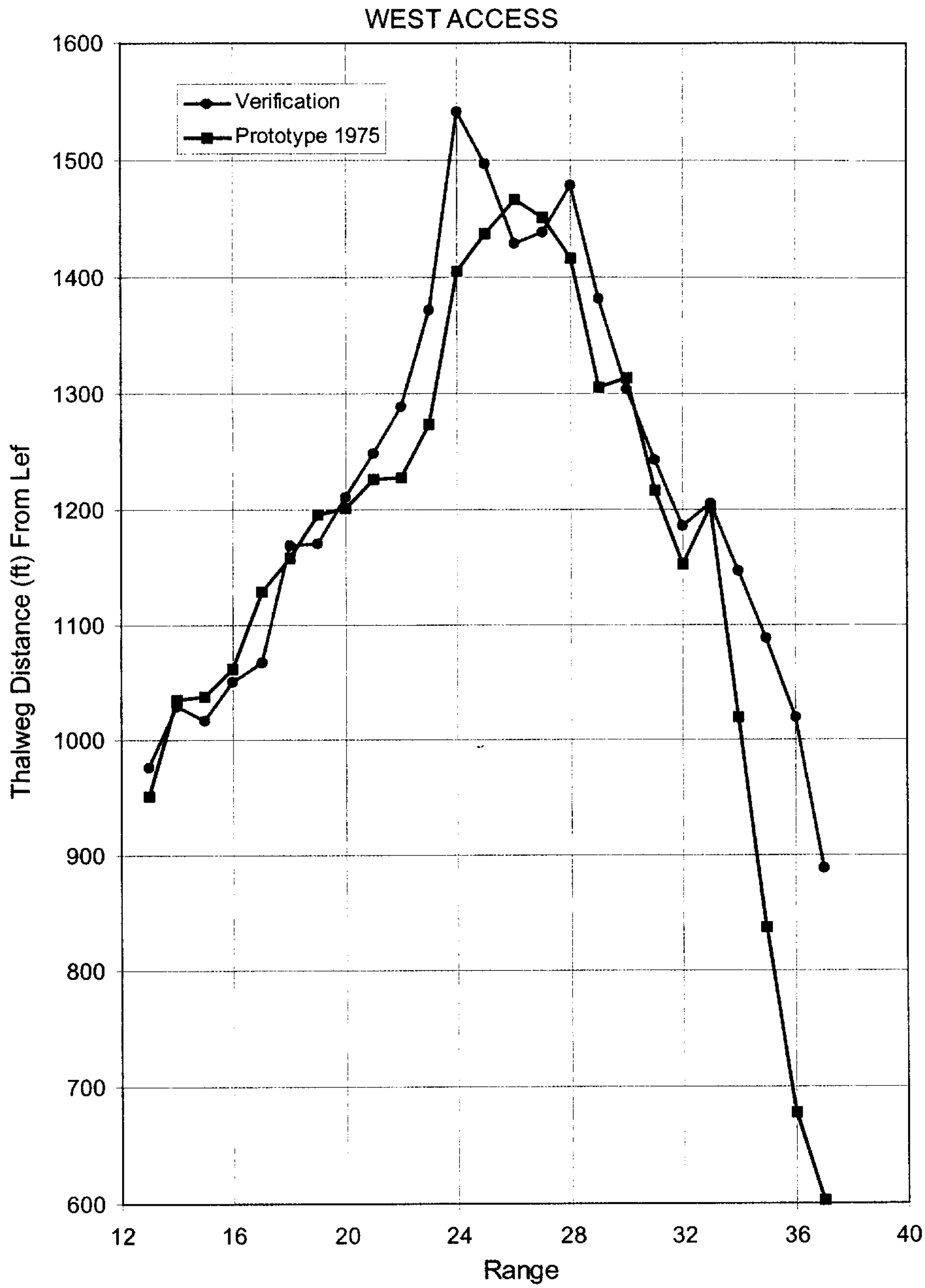

Figure B-15.2a Thalweg Location From Left by Range, West Access

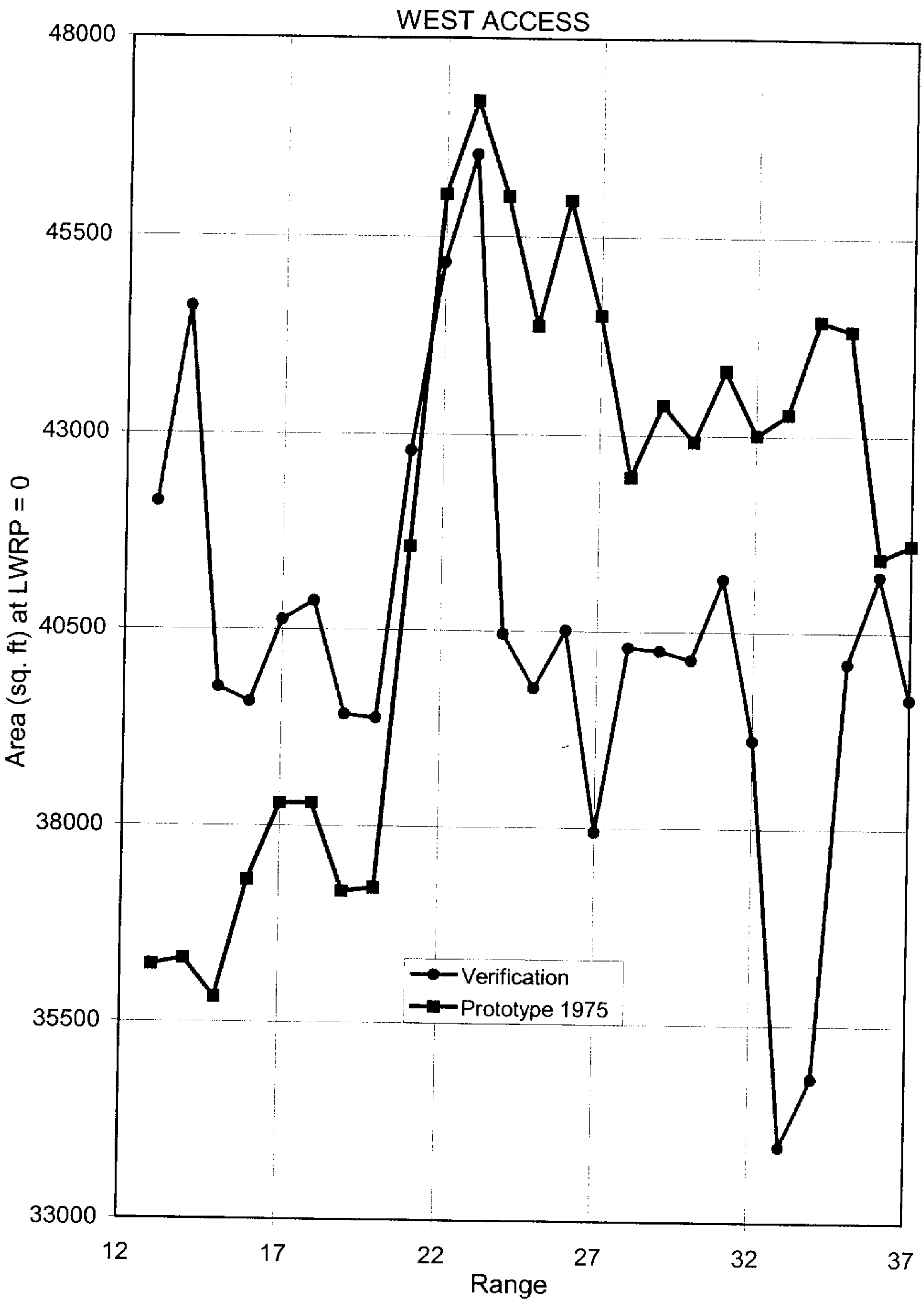

Figure B-15.2b Cross-Section Area by Range, West Access Channel

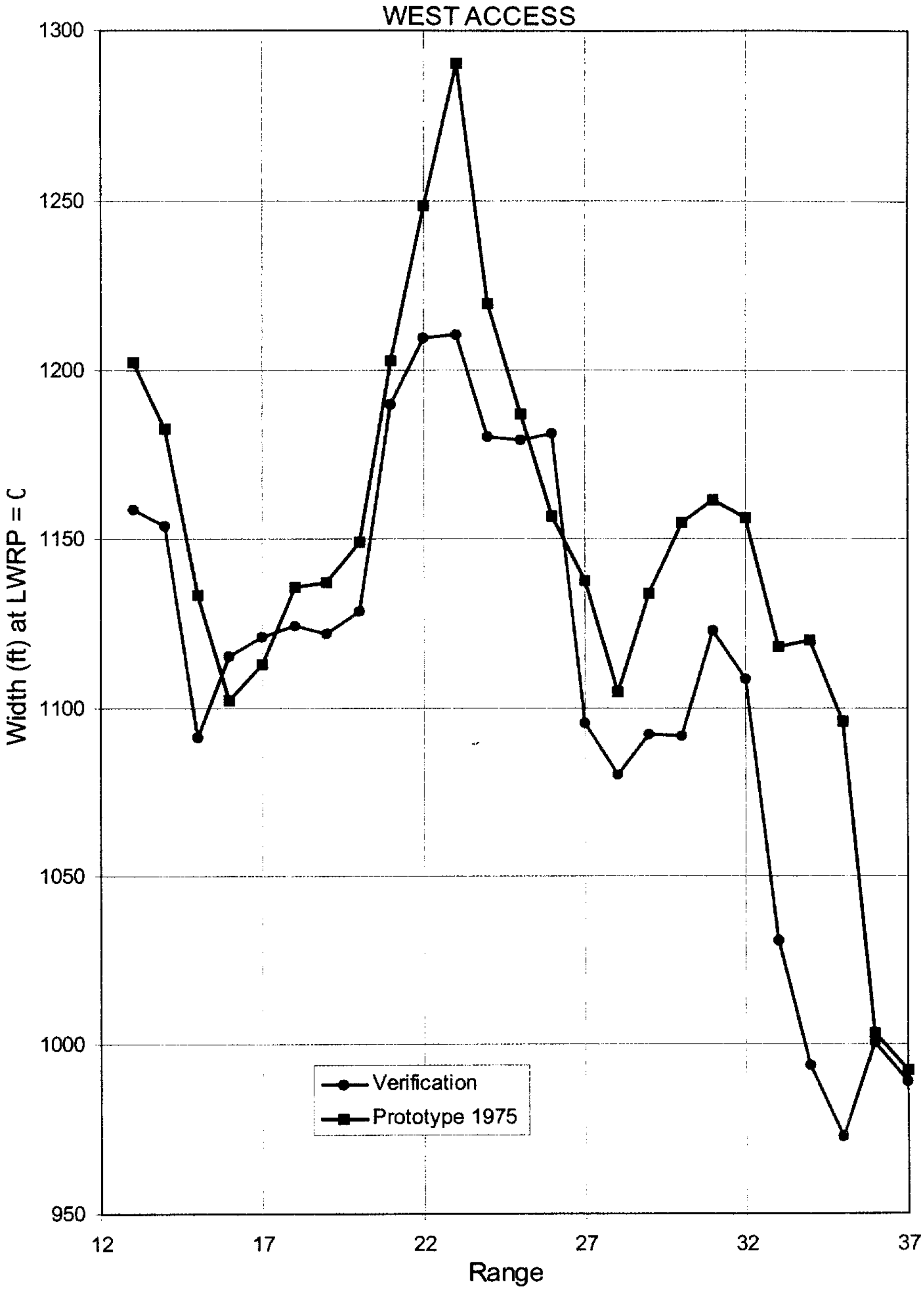

Figure B-15.2c Top Width by Range, West Access Channel

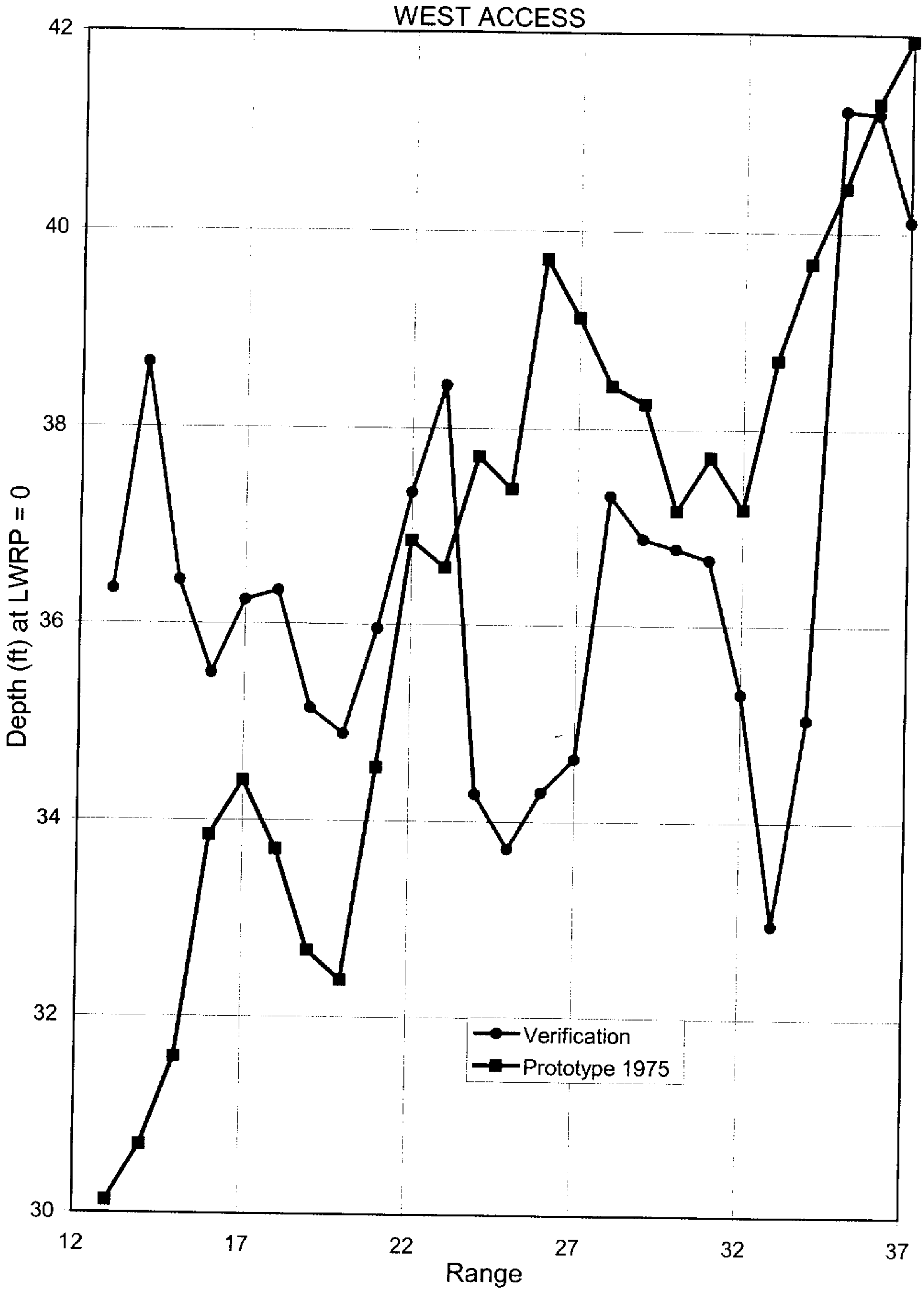

Figure B-15.2d Hydraulic Depth by Range, West Access Channel

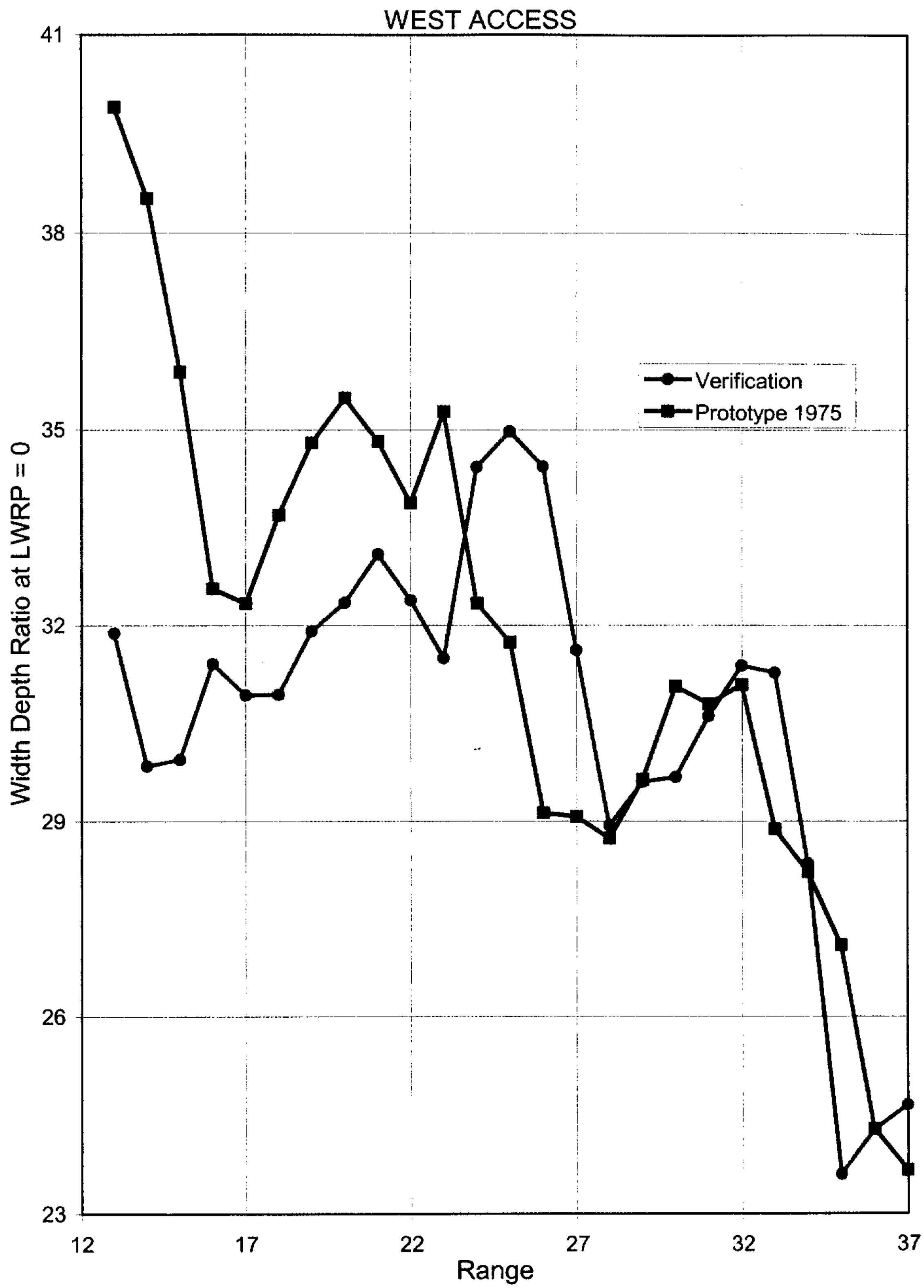

Figure B-15.2e Width/Depth Ratio by Range, West Access Channel

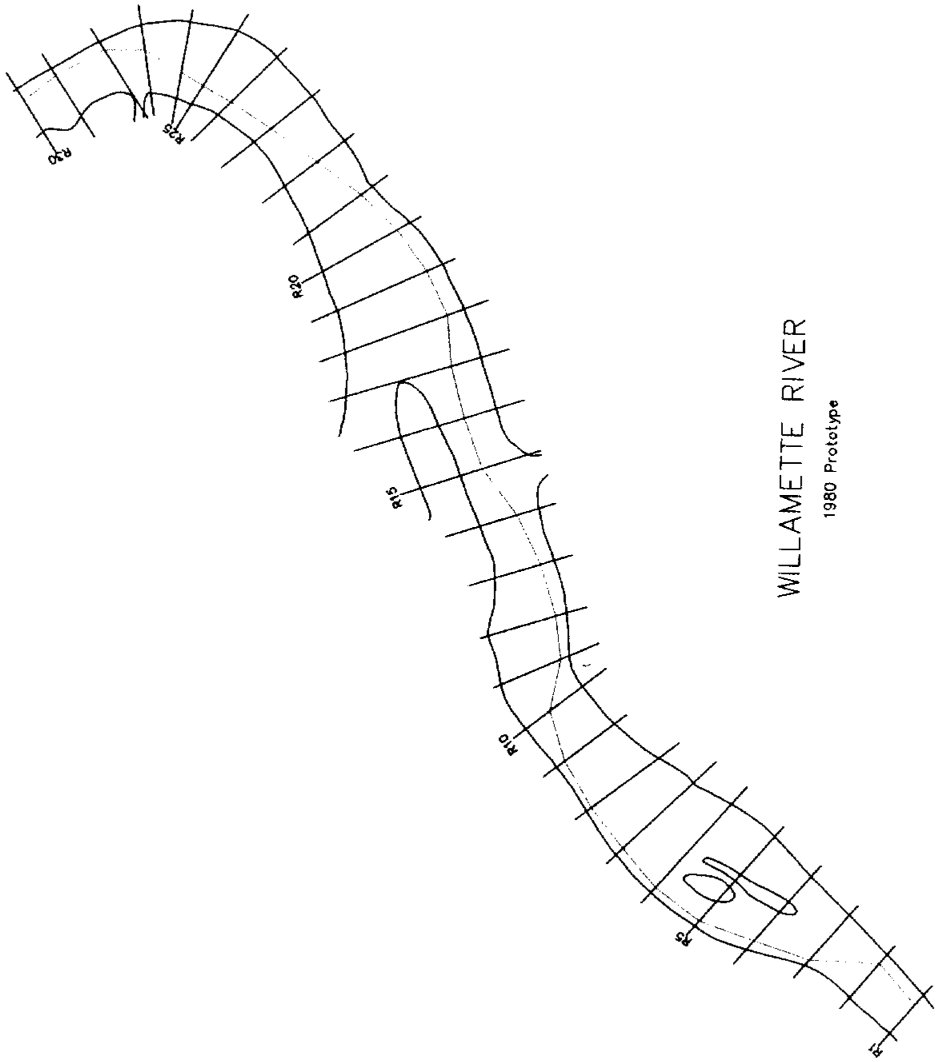

Figure B-16.1a Willamette River Model Plan View

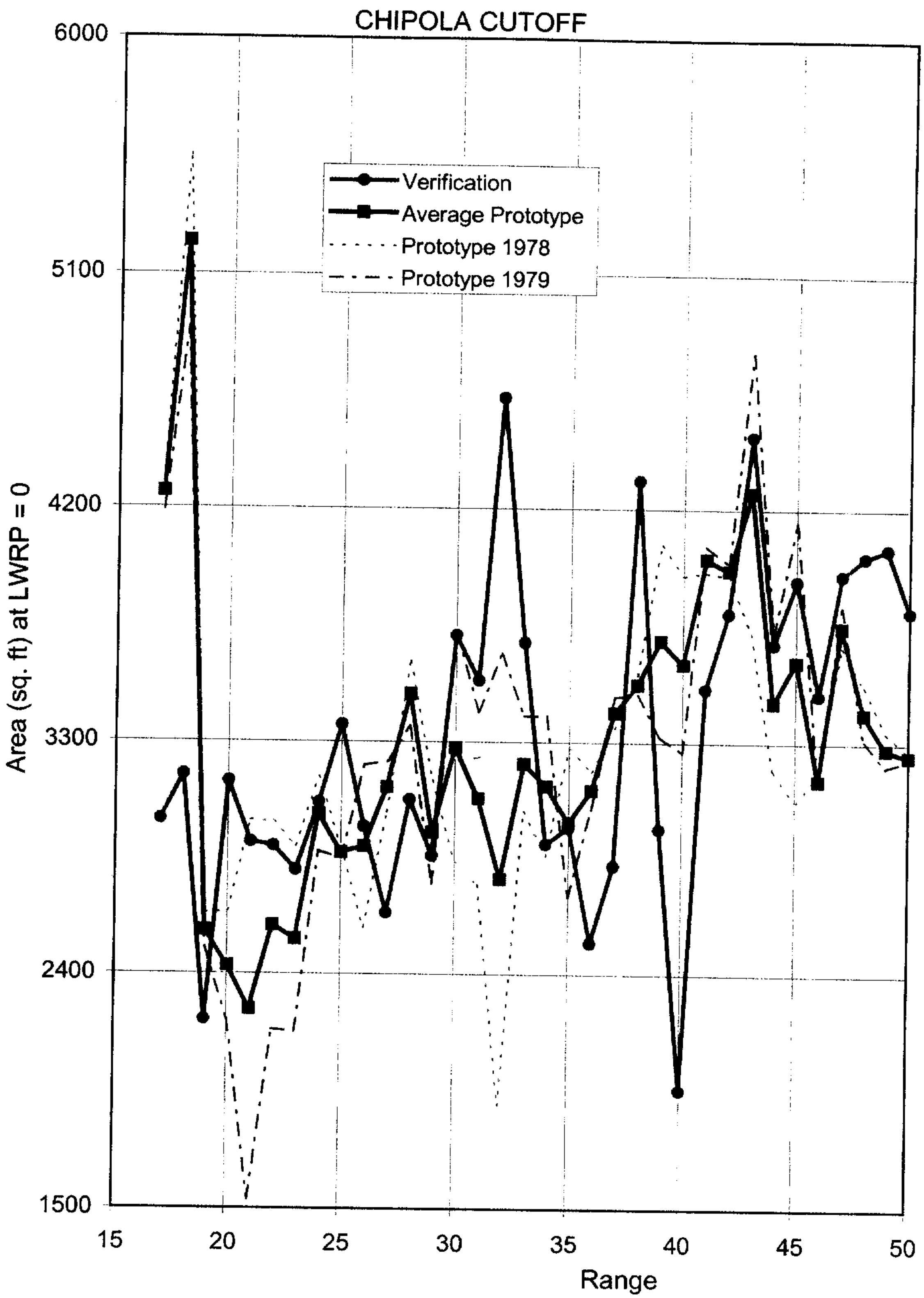

Figure B-4.2b Cross-Section Area by Range, Chipola Cutoff

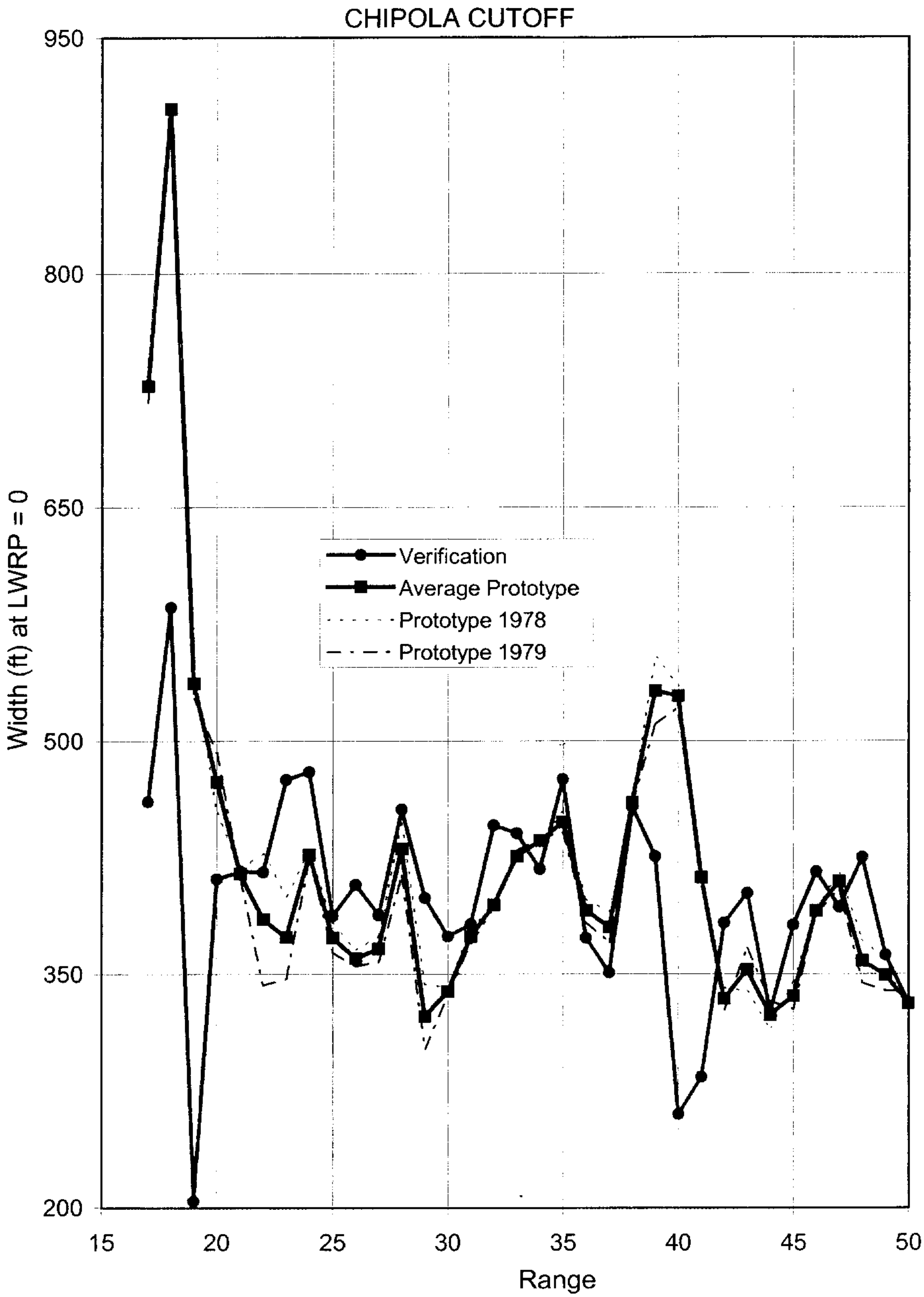

Figure B-4.2c Top Width by Range, Chipola Cutoff

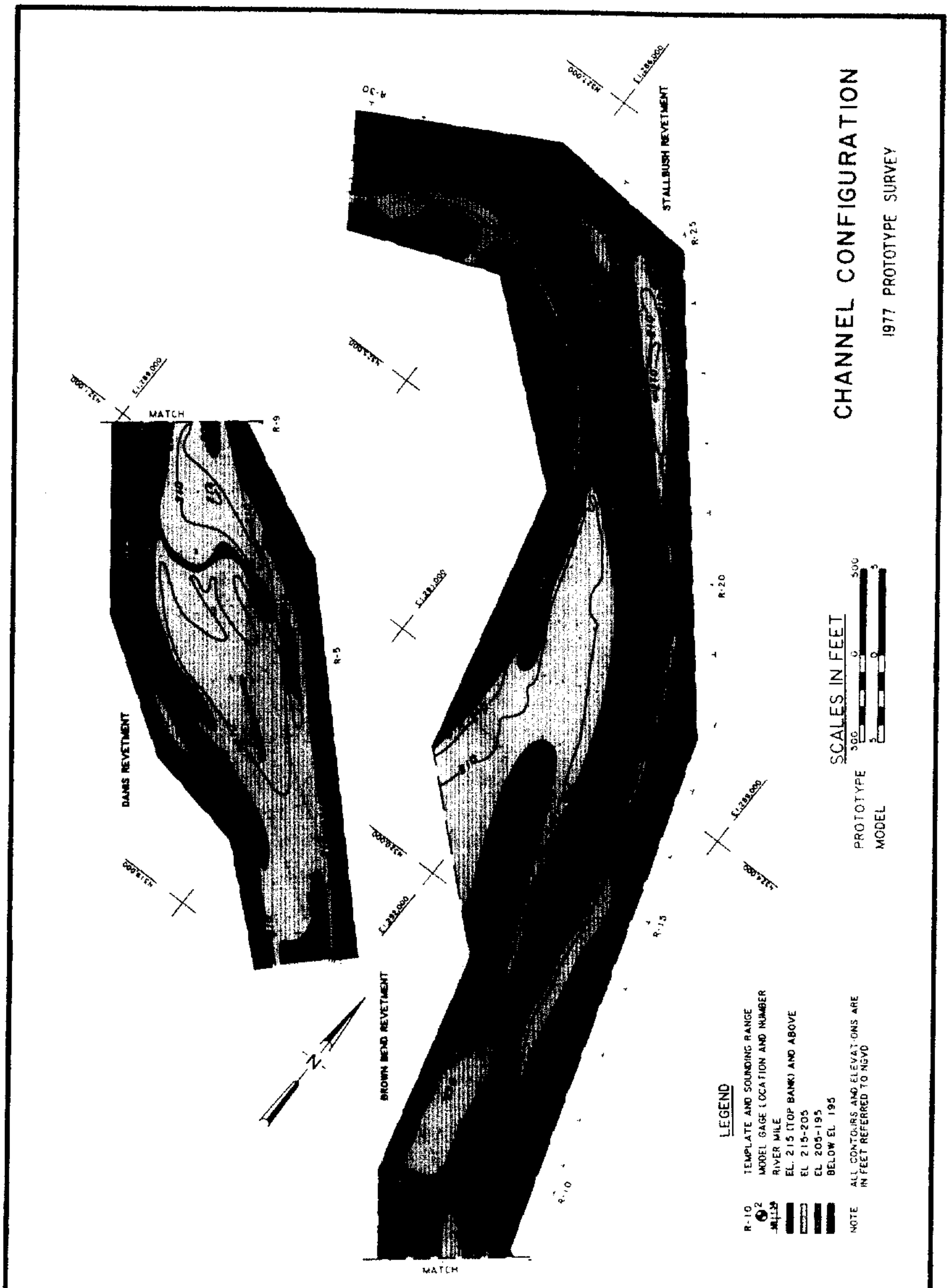

Figure B-16.1b 1977 Willamette River Prototype Survey

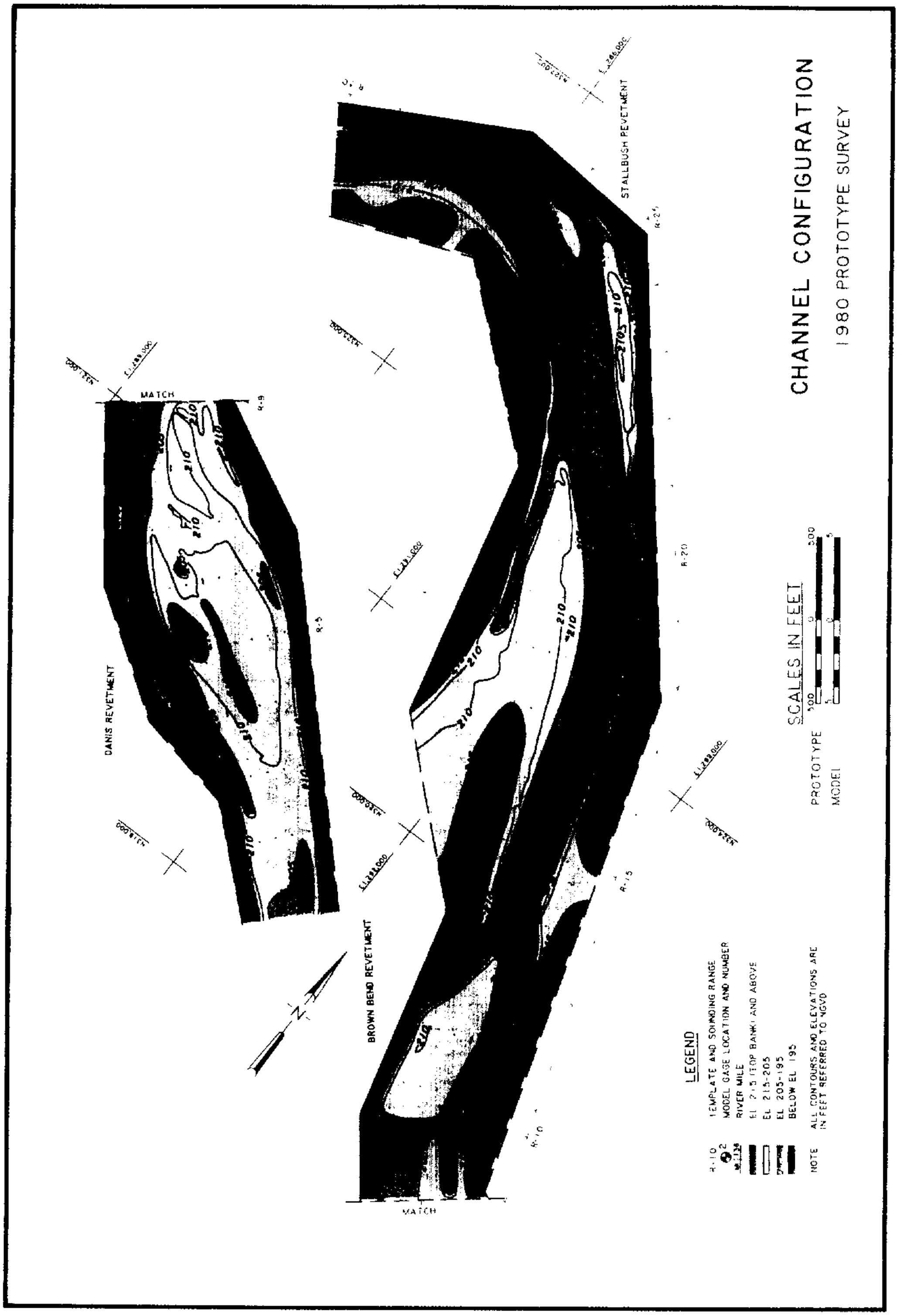

Figure B-16.1c 1980 Willamette River Prototype Survey

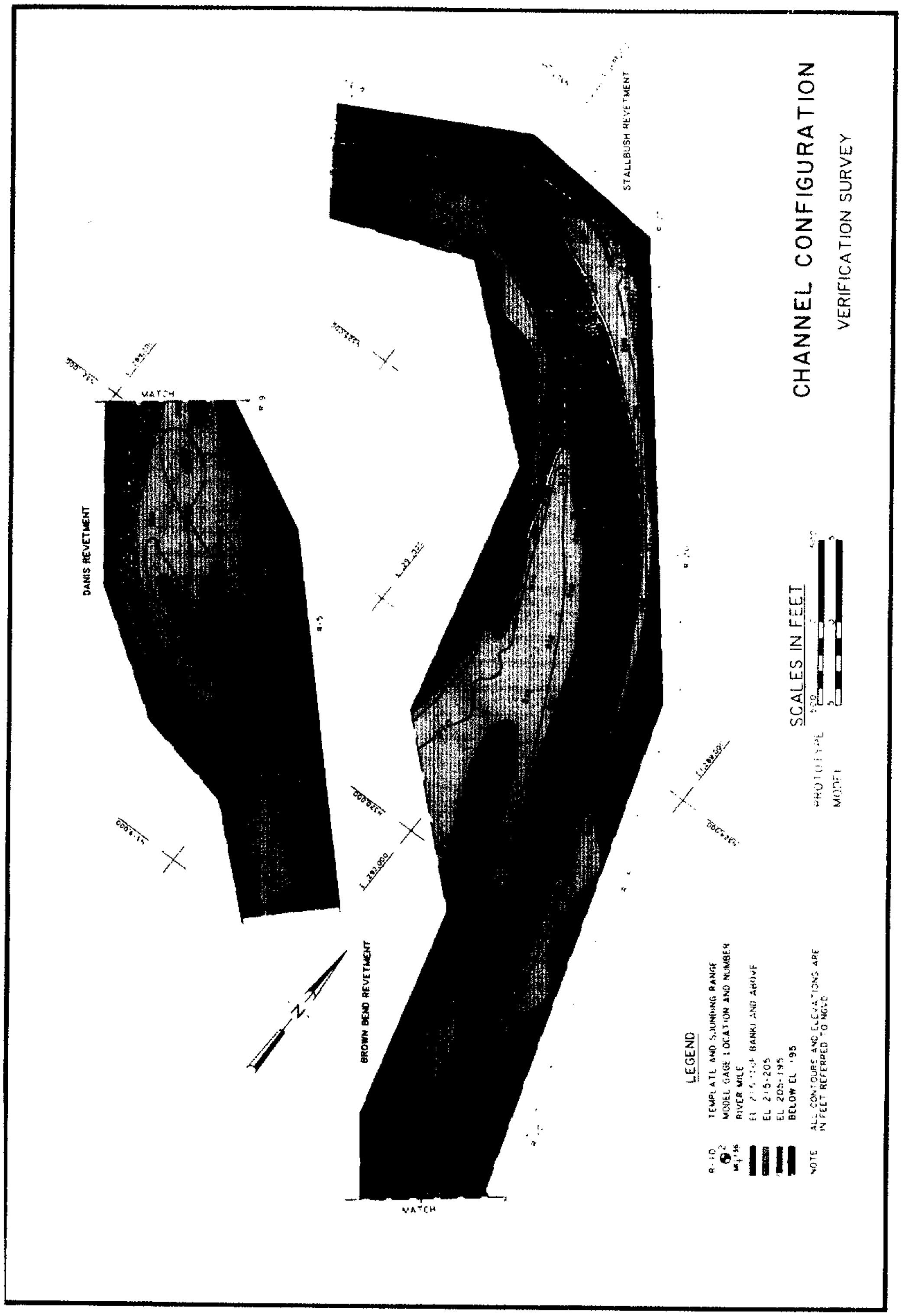

Figure B-16.1d Willamette River Verification Test Survey

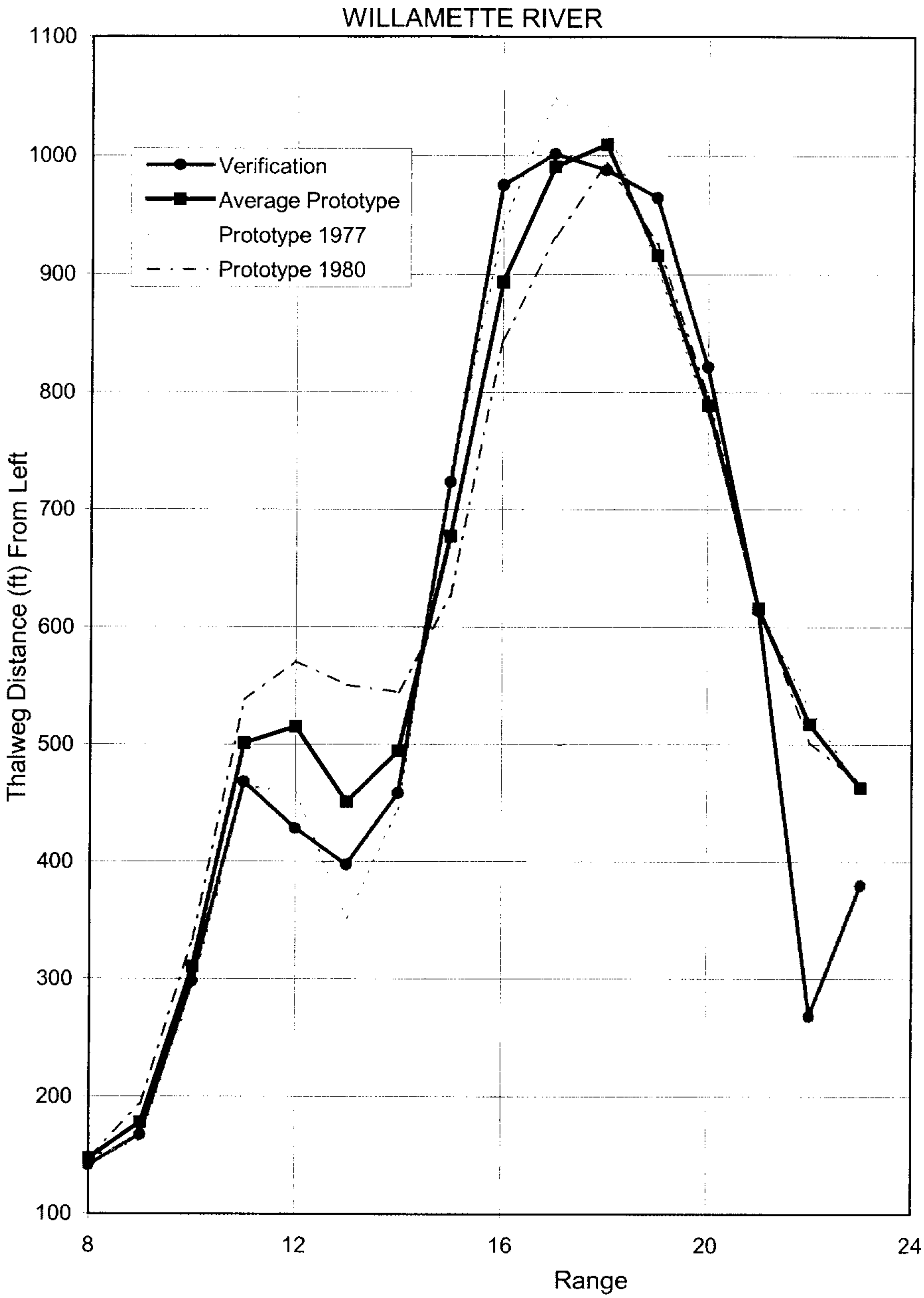

Figure B-16.2a Thalweg Location From Left by Range, Willamette River

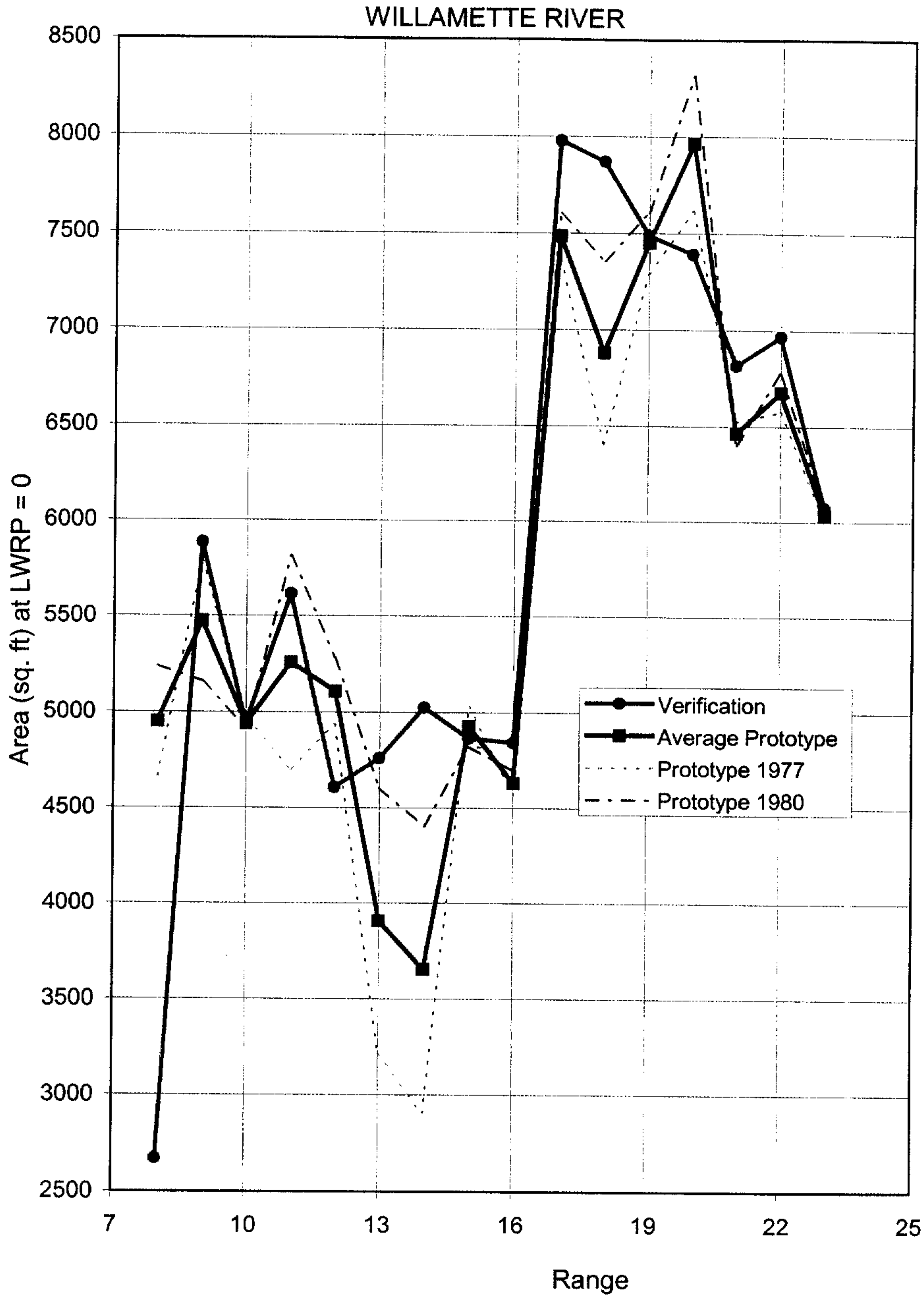

Figure B-16.2b Cross-Section Area by Range, Willamette River

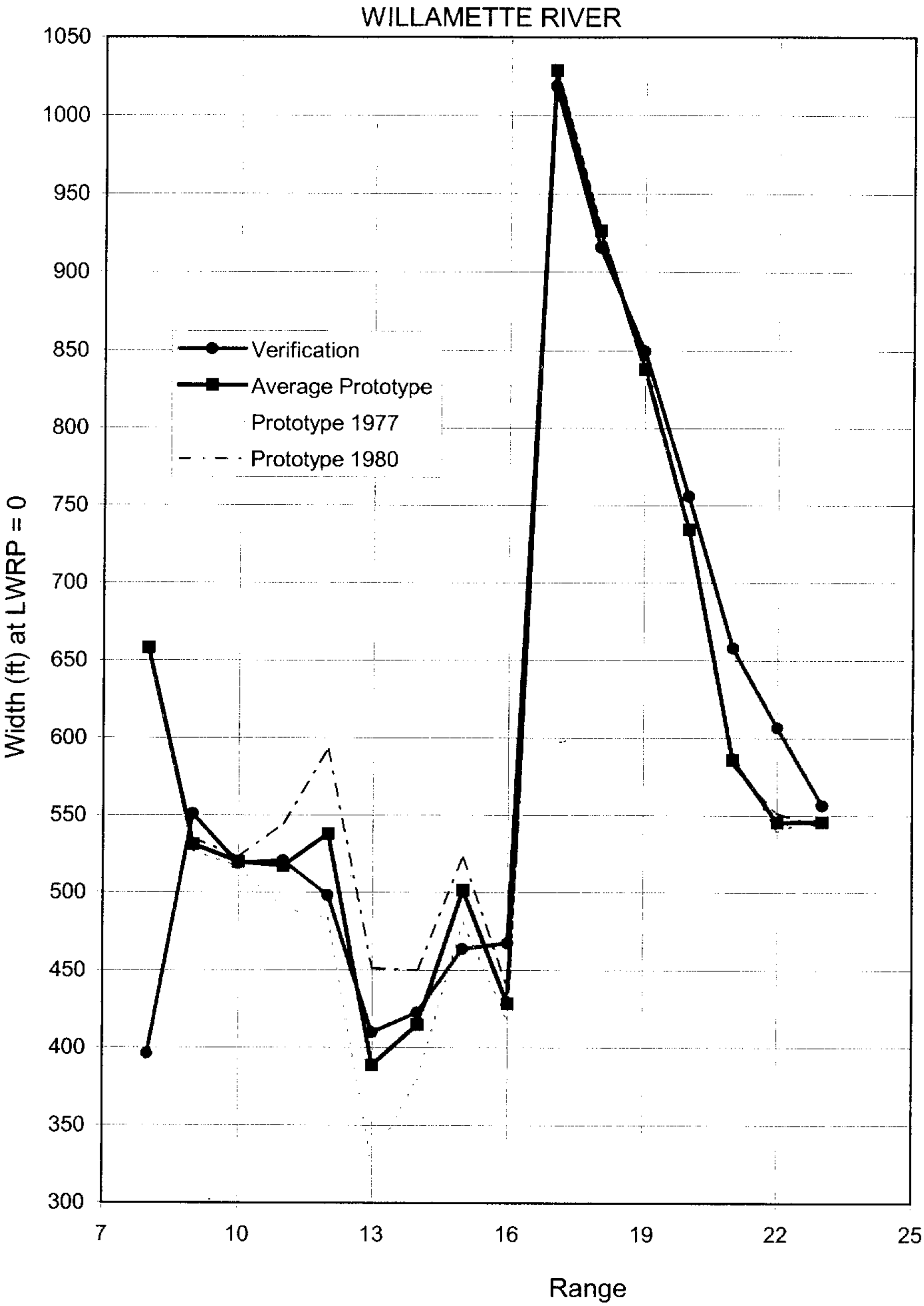

Figure B-16.2c Top Width by Range, Willamette River

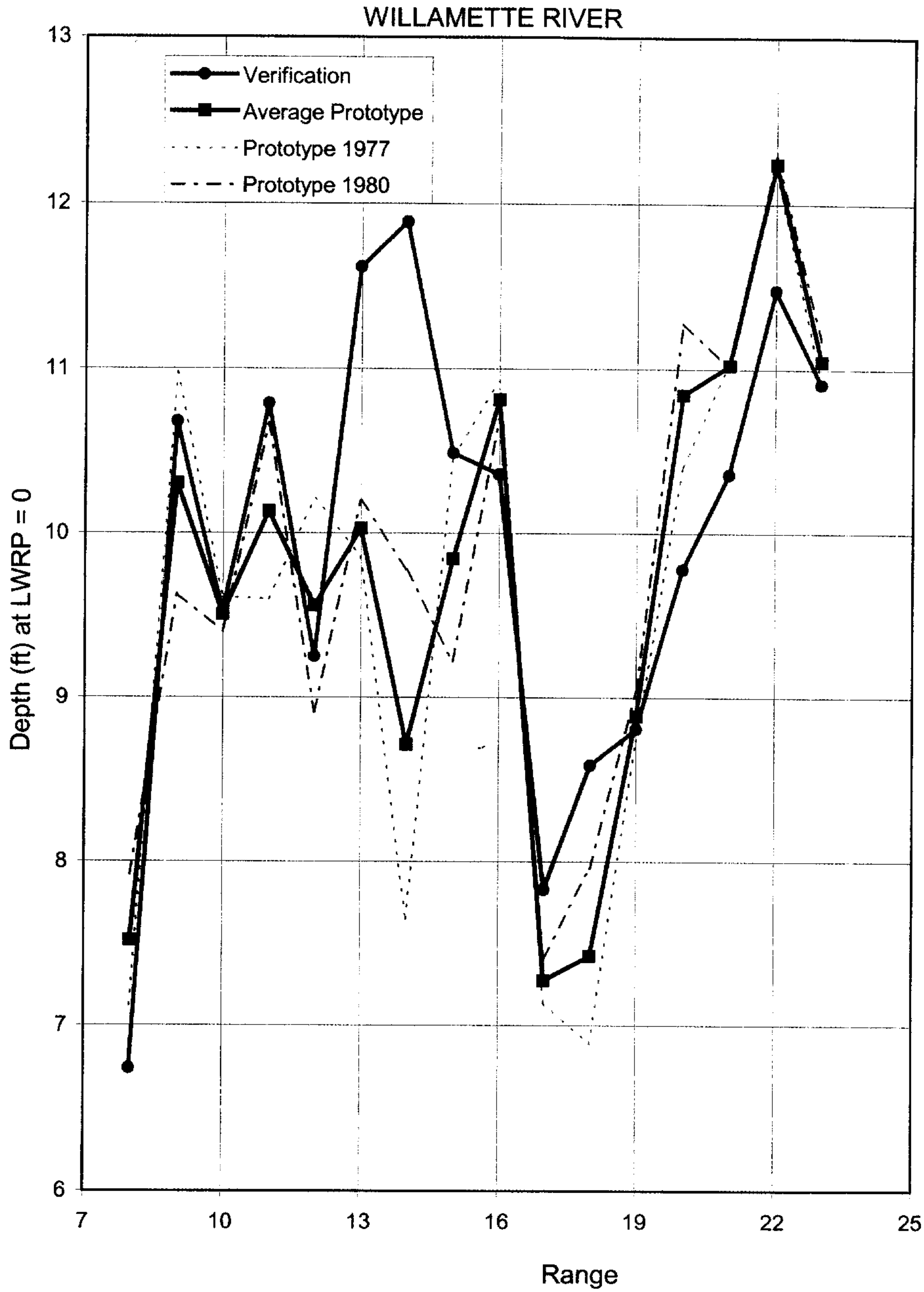

Figure B-16.2d Hydraulic Depth by Range, Willamette River

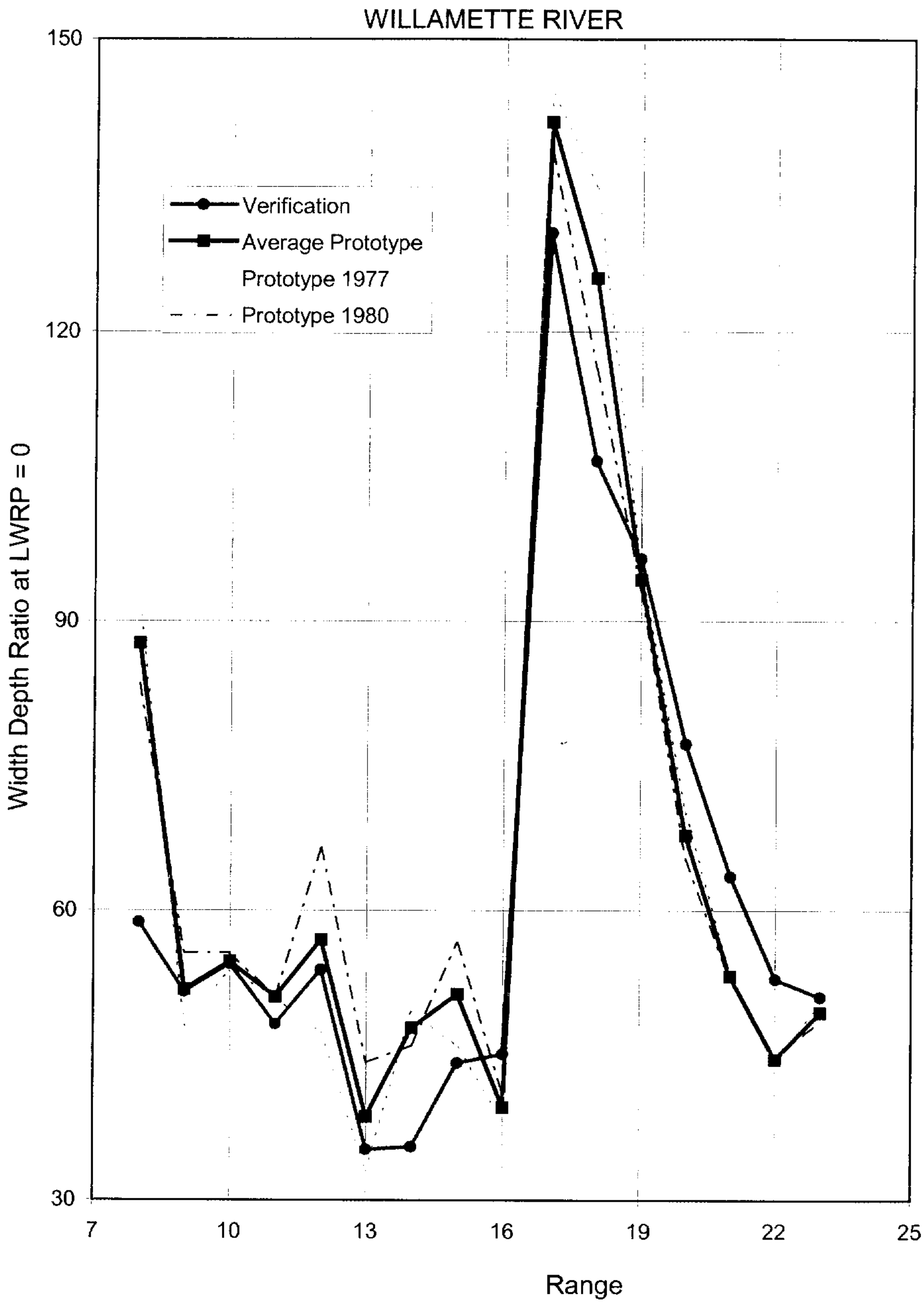

Figure B-16.2e Width/Depth Ratio by Range, Willamette River

APPENDIX C

PREVIOUS MICROMODEL STUDIES

Appendix C: Previous Small-Scale Model Investigations

Name (River)	Prototype Data Used in Model Calibration	Horizontal Scale[a]	Distortion (Horz.: Vert.)
Augusta, AR (White)	1999	3600:1	20:1
Clarendon, AR (White)	1999	4200:1	14:1
Copeland Bend (Missouri)	1991, 1996	3600:1	15:1
Kate Aubrey (Mississippi)[1]	1973, 1975, 1976	8000:1	13.3:1
Kate Aubrey (Mississippi)[1]	1973, 1975, 1976	16000:1	17.8:1
Lock & Dam 24 (Mississippi)	1993, 1995	9600:1	16:1
Memphis Harbor (Mississippi)	1996, 1997	4800:1	8:1
Morgan City/Berwick Bay (Atchafalaya)	1999	7200:1	6:1
New Madrid (Mississippi)	1994	20000:1	16.7:1
Salt Lake (Mississippi)	1993, 1995, 1996, 1998	9600:1	16:1
Savanna Bay (Mississippi)	1996	4800:1	8:1
Vicksburg Front (Mississippi)	1994, 1997	14400:1	12:1
Wolf Island (Mississippi)	1997, 1998	7200:1	12:1

[a]Scale is prototype/model ratio.
[1]Models conducted as part of present research for studying scale effects.

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

LIST OF FIGURES

1.1 Augusta Reach, White River, Arkansas

Location: The Augusta reach is located on the White River about 193 river miles above its confluence with the Mississippi River.

Purpose of Study: The purpose of the study was to investigate structural methods to improve navigation depths and reduce dredging.

Data: Data used in this movable bed micro model included (1) 1999 Prototype Survey (2) Micro Model base test.

Scale: The micro model used in this study had a horizontal scale of 1 inch = 300 feet and a vertical scale of 1 inch = 15 feet, and reproduced approximately 7 miles of the White River between Miles 197 and 190.

Actual Model Limits: RM 201.5 to 189.5

Study Limits: RM 196.2 to 190.0

Reference: John D. Boeckmann, Robert D. Davinroy, David C. Gordon, Aron M. Rhoads (2000) "Sedimentation and Navigation Study of the Lower White River, Near Augusta and Clarendon, Arkansas" Technical Report M12. U.S. Army Engineer District, St. Louis, MO.

1.2 Copeland Bend Reach, Missouri River

Location: The Copeland Bend reach is located on the Missouri River about 567 river miles above its confluence with the Mississippi River.

Purpose of Study: The purpose of this study was to evaluate design alternatives focused on environmental enhancement for the creation of shallow water habitat within Copeland Bend.

Data: Data used in this movable bed analysis included (1) 1991 Prototype Survey (2) 1996 Prototype Survey (3) Micro Model base test.

Scale: The micro model used in this study had a horizontal scale of 1 inch = 300 feet and a vertical scale of 1 inch = 20 feet, and reproduced approximately 5 miles of the Missouri River between Miles 569 and 564.5.

Actual Model Limits: RM 570.0 to 564.0

Study Limits: RM 569.0 to 564.5

Reference: Robert D. Davinroy, David C. Gordon, Aron M. Rhoads, James R. Abbott (1999) "Sedimentation and Navigation Study of the Missouri River, Copeland Bend, Miles 569 to 564.5" Technical Report M10. U.S. Army Engineer District, St. Louis, MO.

1.3 Clarendon Reach, White River, Arkansas

Location: The Clarendon reach is located on the White River about 96 river miles above its confluence with the Mississippi River.

Purpose of Study: The purpose of the study was to investigate structural methods to improve navigation depths and reduce dredging.

Data: Data used in this movable bed micro model included (1) 1999 Prototype Survey (2) Micro Model base test.

Scale: The micro model used in this study had a horizontal scale of 1 inch = 350 feet and a vertical scale of 1 inch = 25 feet, and reproduced approximately 6 miles of the White River between Miles 100 and 94.

Actual Model Limits: RM 100.1 to 93.0

Study Limits: RM 99.8 to 93.5

Reference: John D. Boeckmann, Robert D. Davinroy, David C. Gordon, Aron M. Rhoads (2000) "Sedimentation and Navigation Study of the Lower White River, Near Augusta and Clarendon, Arkansas" Technical Report M12. U.S. Army Engineer District, St. Louis, MO.

1.4 Kate Aubrey Reach, Mississippi River

Please See Chapter 3 for complete information

1.5 Lock and Dam 24 Reach, Upper Mississippi River

Location: Lock and Dam 24 is located on the Upper Mississippi River about 273 river miles above its confluence with the Ohio River.

Purpose of Study: The purpose of the Lock and Dam 24 micro model study was to investigate possible solutions to the dangerous outdraft currents that existed at the downstream approach to the lock.

Data: Data used in the Movable bed analysis included: (1) 1993 Prototype survey, (2) 1995 Prototype survey and, (3) Micro Model base test.

Scale: The micro model used in this study had a horizontal scale of 1 inch = 800 feet and a vertical scale of 1 inch = 50 feet, and reproduced approximately 6 miles of the Upper Mississippi River between Miles 271 and 277.

Actual Model Limits: RM 281.0 to 270.0

Study Limits: RM 277.0 to 272.0

Reference: Robert D. Davinroy, David C. Gordon, Robert D. Hetrick (1998). "Navigation Study at the Approach to Lock and Dam 24, Upper Mississippi River" Technical Report M2, U.S. Army Engineer District, St. Louis, MO.

1.6 Memphis Harbor Reach, Lower Mississippi River

Location: Memphis Harbor is located on the Lower Mississippi River about 739 river miles above the Head of Passes.

Purpose of Study: The purpose of the Memphis Harbor study was to evaluate proposed design enhancements at the harbor.

Data: Data used in the movable bed analysis included (1) 1996 Prototype Survey (2) 1997 Prototype Survey (3) Micro Model base test.

Scale: The micro model used in this study had a horizontal scale of 1 inch = 500 feet and a vertical scale of 1inch = 50 feet, and reproduced approximately 7 miles of the Lower Mississippi River between miles 742 and 735.

Actual Model Limits: RM 743.0 to 734.0

Study Limits: RM 741.5 to 735.0

Reference: Robert D. Davinroy, David C. Gordon, Edward H. Riiff, (2000) "Sedimentation Study at Memphis Harbor, Lower Mississippi River, River Miles 742 at 735" Technical Report M8. U.S. Army Engineer District, St. Louis, MO.

1.7 Morgan City/Berwick Bay Reach, Atchafalaya River, Louisiana

Location: Morgan City is located on the Atchafalaya River about 120 river miles below the Old River Control Structure and the Mississippi River.

Purpose of Study: The purpose of the study was to improve navigation depths, reduce dredging, and improve navigation alignment through several bridge spans.

Data: Data used in this movable bed study included (1) 1999 Prototype Survey (2) Micro Model base test.

Scale: The micro model used in this study had a horizontal scale of 1 inch = 600 feet and a vertical scale of 1 inch = 100 feet, and reproduced approximately 6 miles of the Atchafalaya River between Miles 124 and 118.5.

Actual Model Limits: RM 116.5 to 126.0

Study Limits: RM 119.0 to 124.0

Reference: Robert D. Davinroy, David C. Gordon, Edward H. Riiff, Aron M. Rhoads, (2001) "Sedimentation and Navigation Study of the Lower Atchafalaya River at Morgan City and Berwick, Louisiana, River Miles 124.0 to 118.5, Hydraulic Micro Model Study" Technical Report M14. U.S. Army Engineer District, St. Louis, Mo.

1.8 New Madrid Reach, Lower Mississippi River

Location: New Madrid is located on the Lower Mississippi River about 889 river miles above the Head of Passes.

Purpose of Study: The purpose of the New Madrid study was to improve navigation depths and alignment.

Data: Data used in the movable bed analysis included (1) 1994 Prototype Survey (2) Micro Model base test.

Scale: The micro model used in this study had a horizontal scale of 1 inch = 1667 feet and a vertical scale of 1 inch = 100 feet, and reproduced approximately 8 miles of the Lower Mississippi River between Miles 891 and 883.

Actual Model Limits: RM 899.0 to 881.0

Study Limits: RM 890.0 to 884.0

Reference: Robert D. Davinroy (1995) "Sedimentation Study of the Mississippi River, New Madrid Bar Reach, River Miles 891 at 883, Hydraulic Micro Model Investigation" U.S. Army Engineer District, St. Louis, MO.

1.9 Salt Lake Chute Reach, Middle Mississippi River

Location: Salt Lake Chute is located on the Middle Mississippi River about 138 river miles above its confluence with the Ohio River.

Purpose of Study: The purpose of the Salt Lake Chute Micro Model study was to investigate design alternatives that were intended to improve environmental health and enhance side channel habitat.

Data: Data used in this movable bed study included (1) 1989 Prototype Survey (2) 1993 Prototype Survey (3) 1995 Prototype Survey (4) 1996 Prototype Survey (5) 1998 Prototype Survey (6) Micro Model base test.

Scale: The micro model used in this study had a horizontal scale of 1 inch = 800 feet and a vertical scale of 1 inch = 50 feet, and reproduced approximately 8 miles of the Middle Mississippi River between river miles 141 and 133.

Actual Model Limits: RM 142.5 to 131.0

Study Limits: RM 140.5 to 136.0

Reference: David C. Gordon, Robert D. Davinroy, Peter M. Russell (2001) "Sedimentation Study of the Middle Mississippi River at Salt Lake Chute, River Miles 141 to 133" Technical Report M16, U.S. Army Engineer District, St. Louis, MO.

1.10 Vicksburg Front, Lower Mississippi River

Location: Vicksburg Front is located on the Lower Mississippi River about 437 river miles above the Head of Passes.

Purpose of Study: The purpose of the Vicksburg Front Micro Model study was to improve navigation alignment for tows traveling through the reach.

Data: Data used in this movable bed study included (1) 1994 Prototype Survey (2) 1997 Prototype Survey (2) Micro Model base test.

Scale: The micro model used in this study had a horizontal scale of 1 inch = 1200 feet and a vertical scale of 1 inch = 100 feet, and reproduced approximately 12 miles of the Lower Mississippi River between 441 and 429.

Actual Model Limits: RM 444.5 to 423

Study Limits: RM 440.0 to 432.5

Reference: Robert D. Davinroy, David C. Gordon, Aron M. Rhoads, James R. Abbott (2000) "Sedimentation and Navigation Study at Vicksburg Front, Lower Mississippi River Miles 441 to 429, Hydraulic Micro Model Study" Technical Report M15. U.S. Army Engineer District, St. Louis, Mo.

1.11 White River Confluence Reach, Lower Mississippi River

Location: The confluence of the Lower Mississippi River and the White River is located about 599 river miles above the Head of Passes.

Purpose of Study: The purpose of this study was to improve navigation alignment and currents at the confluence of the White and Mississippi Rivers.

Data: Data used in the movable bed analysis included (1) 1994 Prototype Survey (2) 1997 Prototype Survey (3) Micro model base test

Scale: The micro model used in this study had a horizontal scale of 1 inch = 1000 feet and a vertical scale of 1 inch = 100 feet, and reproduced approximately 7 miles of the Lower Mississippi River between Miles 596 and 603.

Actual Model Limits: RM 605.0 to 587.0

Study Limits: RM 600.0 to 597.5

Reference: David C. Gordon, Robert D. Davinroy, and Edward H. Riiff, (1998) "Sedimentation and Navigation Study of the Lower Mississippi River at the White River Confluence, Miles 603 to 596" Technical Report M7, U.S. Army Engineer District, St. Louis, MO.

1.12 Wolf Island Reach, Lower Mississippi River

Location: Wolf Island is located on the Lower Mississippi River about 934 river miles above the Head of Passes.

Purpose of Study: The purpose of this study was to improve navigation and enhance the side channel bathymetry and habitat.

Data: Data used in this movable bed analysis included (1) 1998 Prototype Survey (2) 1997 Prototype Survey (3) Micro Model base test

Scale: The micro model used in this study had a horizontal scale of 1 inch = 600 feet and a vertical scale of 1 inch = 50 feet, and reproduced approximately 8 miles of the Lower Mississippi River between Miles 937 and 929.

Actual Model Limits: RM 938.5 to 929.0

Study Limits: RM 937.0 to 930.5

Reference: Robert D. Davinroy, David C. Gordon, Aron M. Rhoads, Edward H Riiff (2000) "Environmental and Navigation Improvement Study of Wolf Island, Mississippi River Miles 936.5 to 929" Technical Report M9. U.S. Army Engineer District, St Louis, MO.

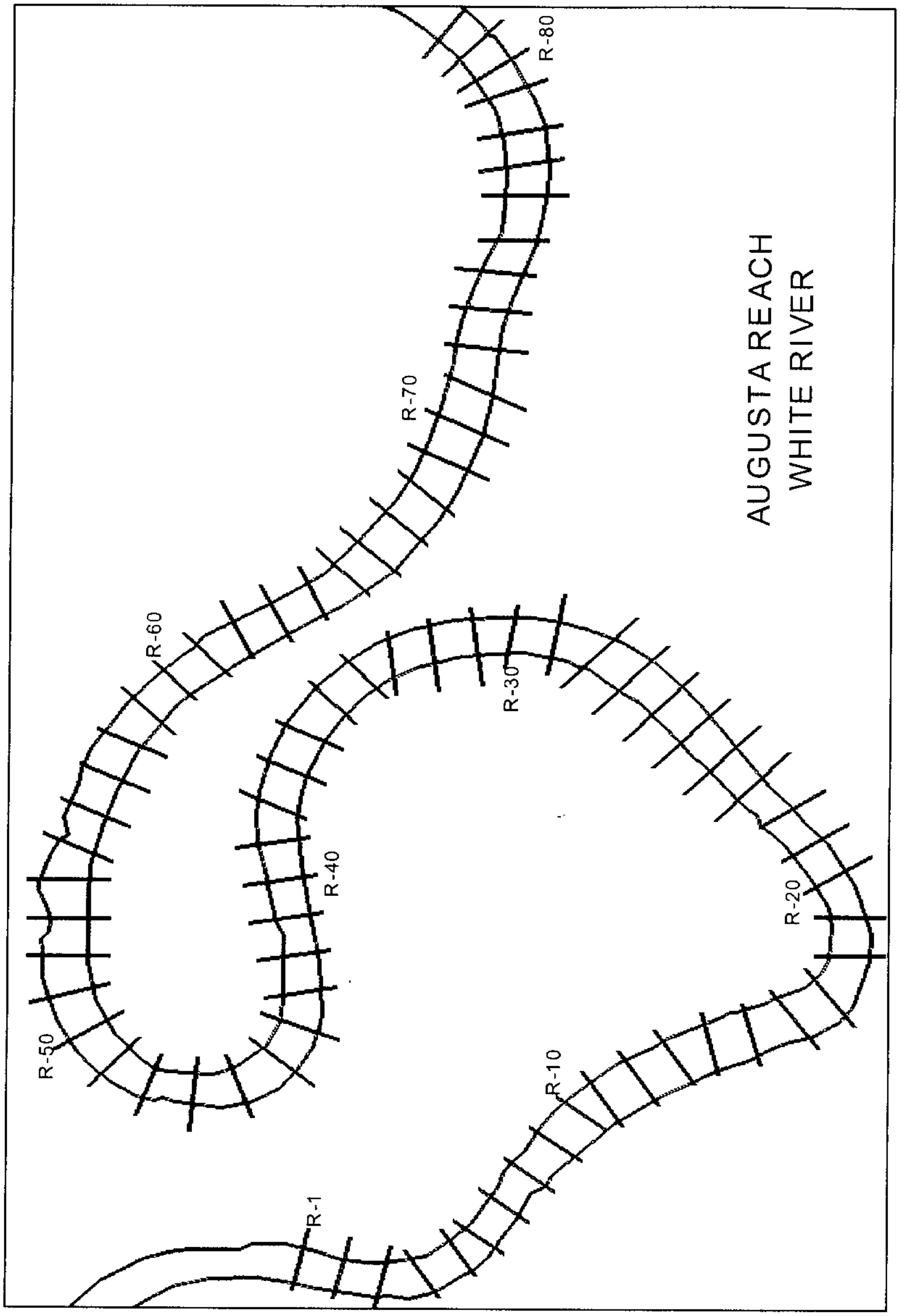

Figure C–1.1a Augusta Model Plan View

Figure C–1.1b 1999 Augusta Prototype Survey

Figure C–1.1c Augusta Micromodel Base Test

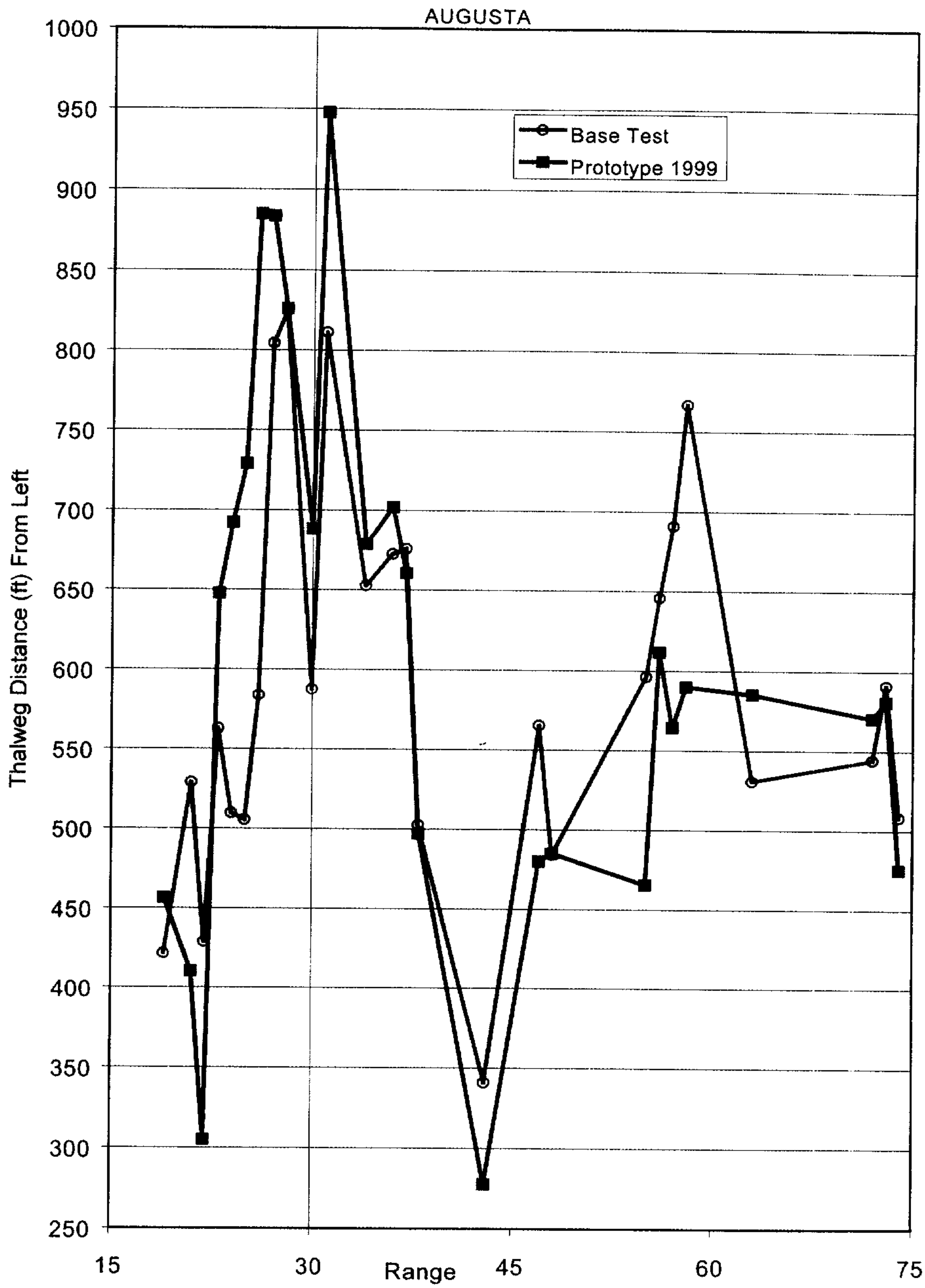

Figure C–1.2a Thalweg Distance From Left by Range, Augusta Reach (White River)

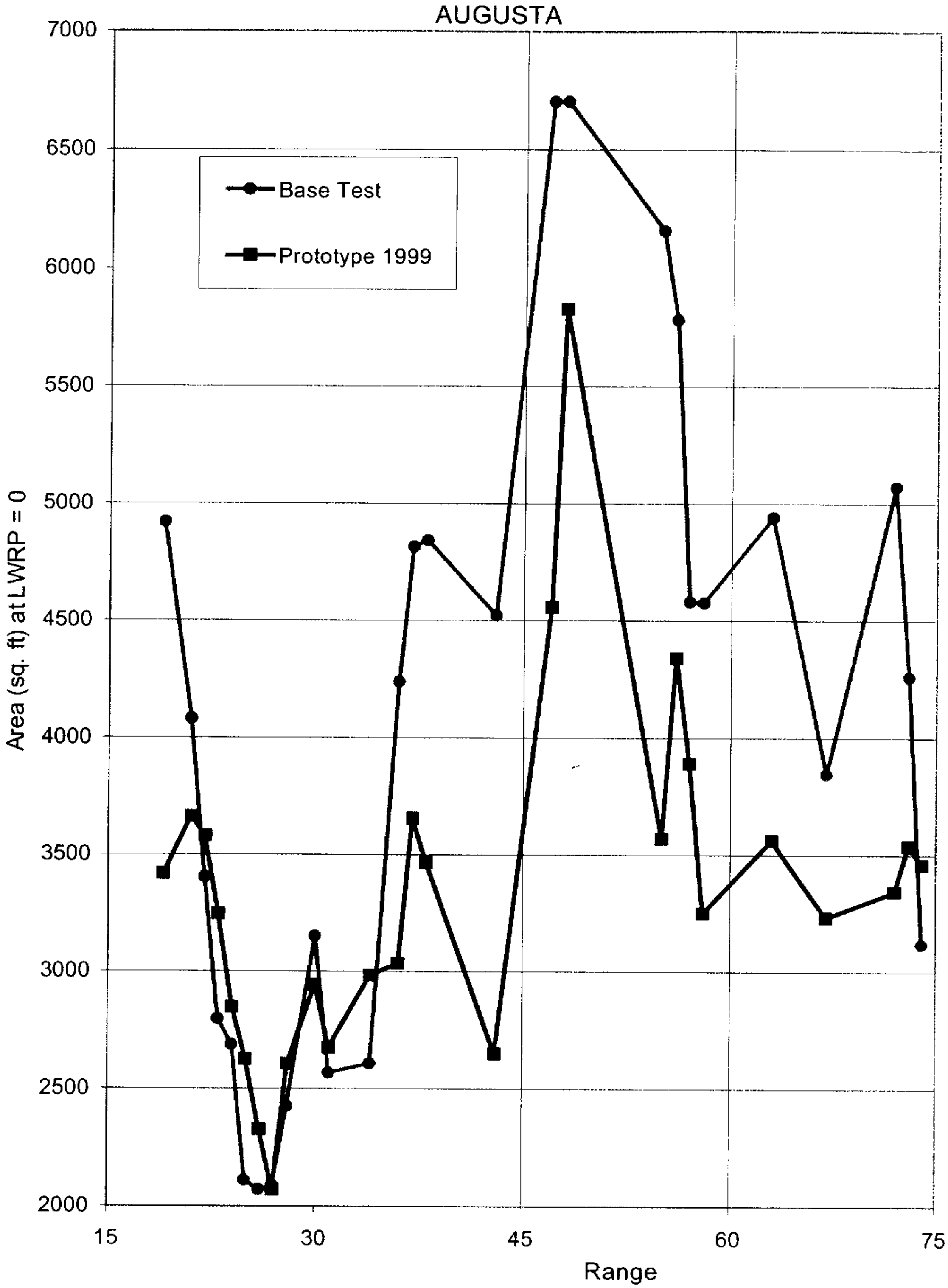

Figure C–1.2b Cross-Section Area by Range, Augusta (White River)

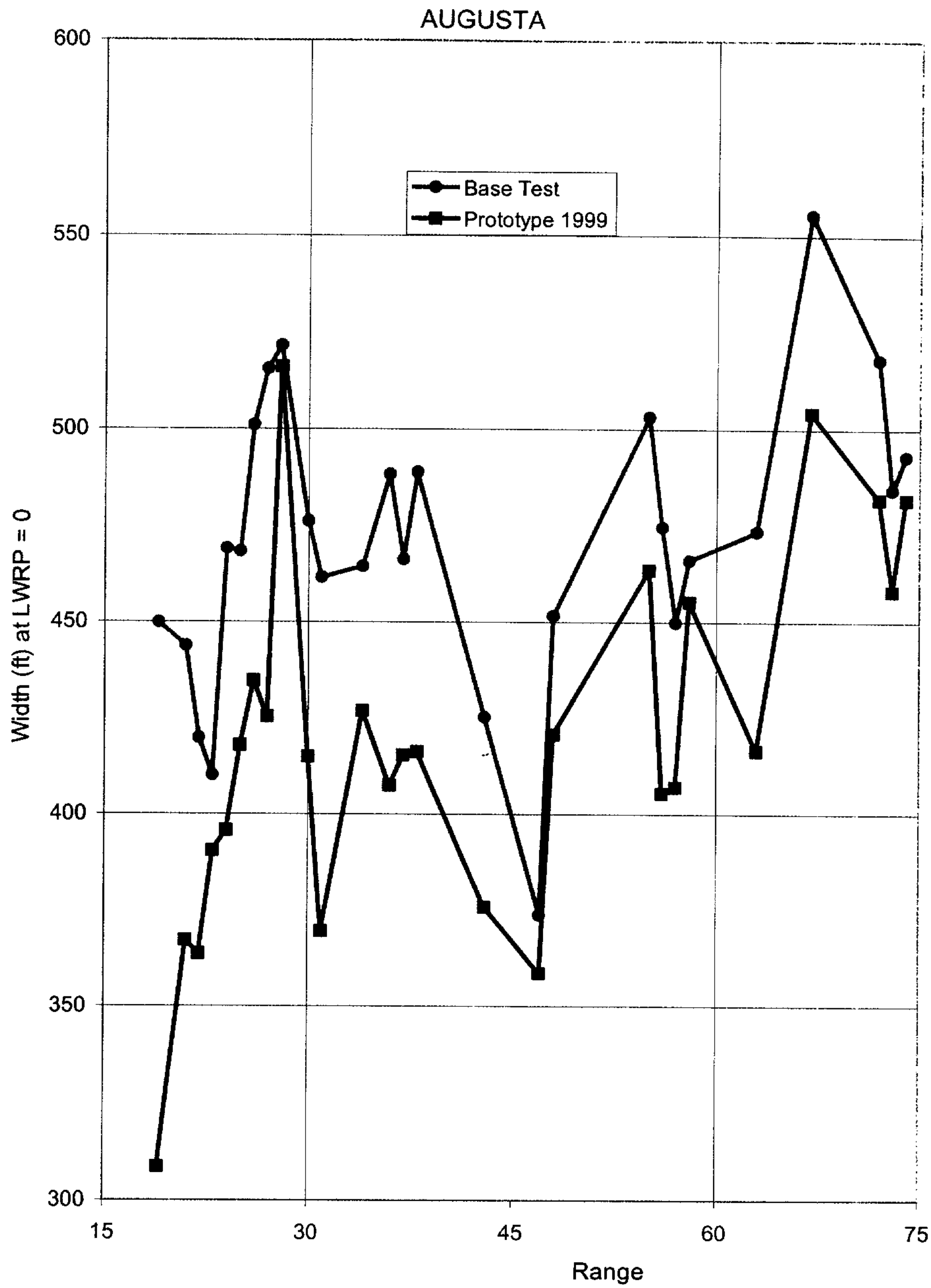

Figure C–1.2c Top Width by Range, Augusta (White River)

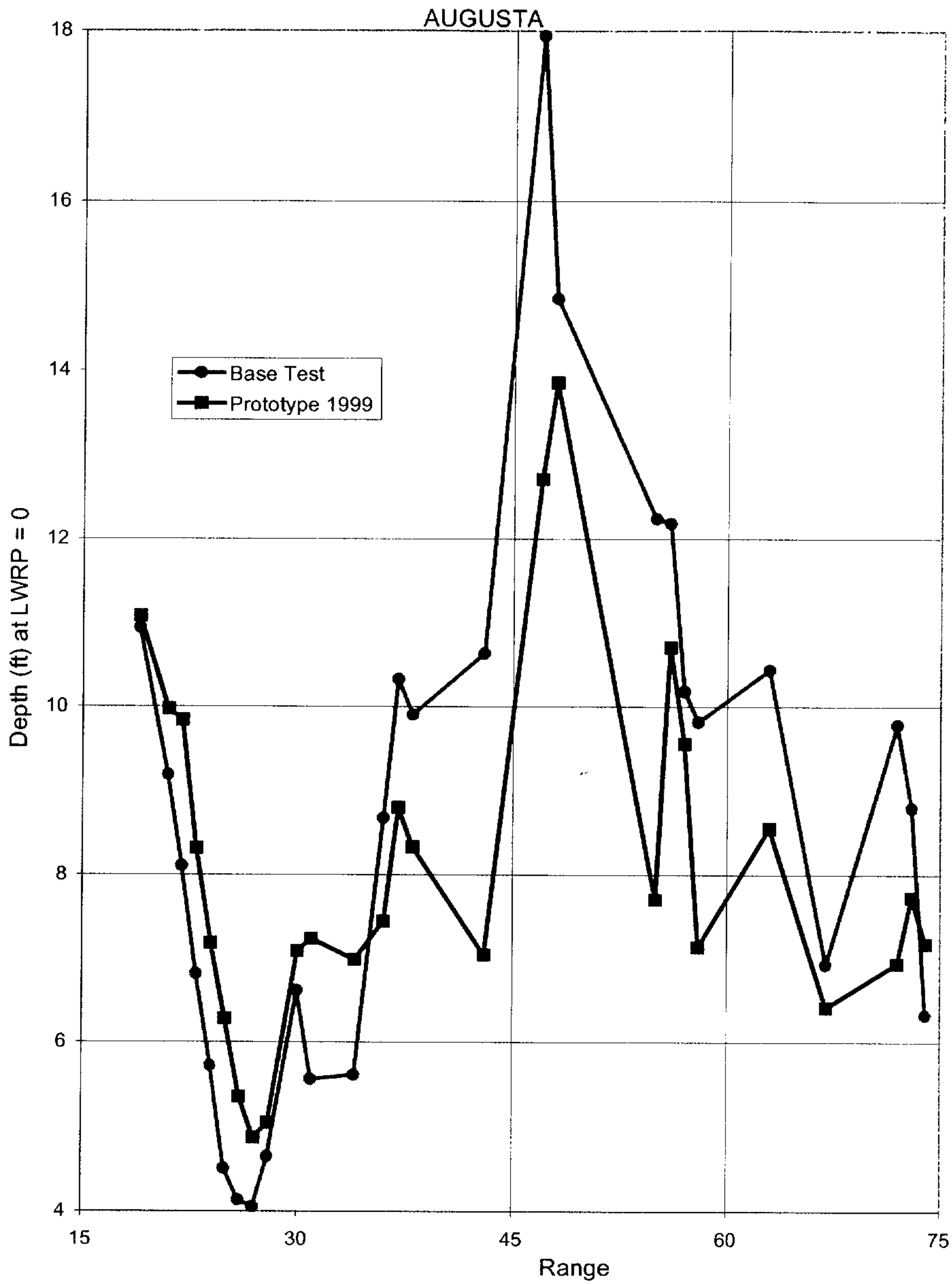

Figure C–1.2d Hydraulic Depth by Range, Augusta (White River)

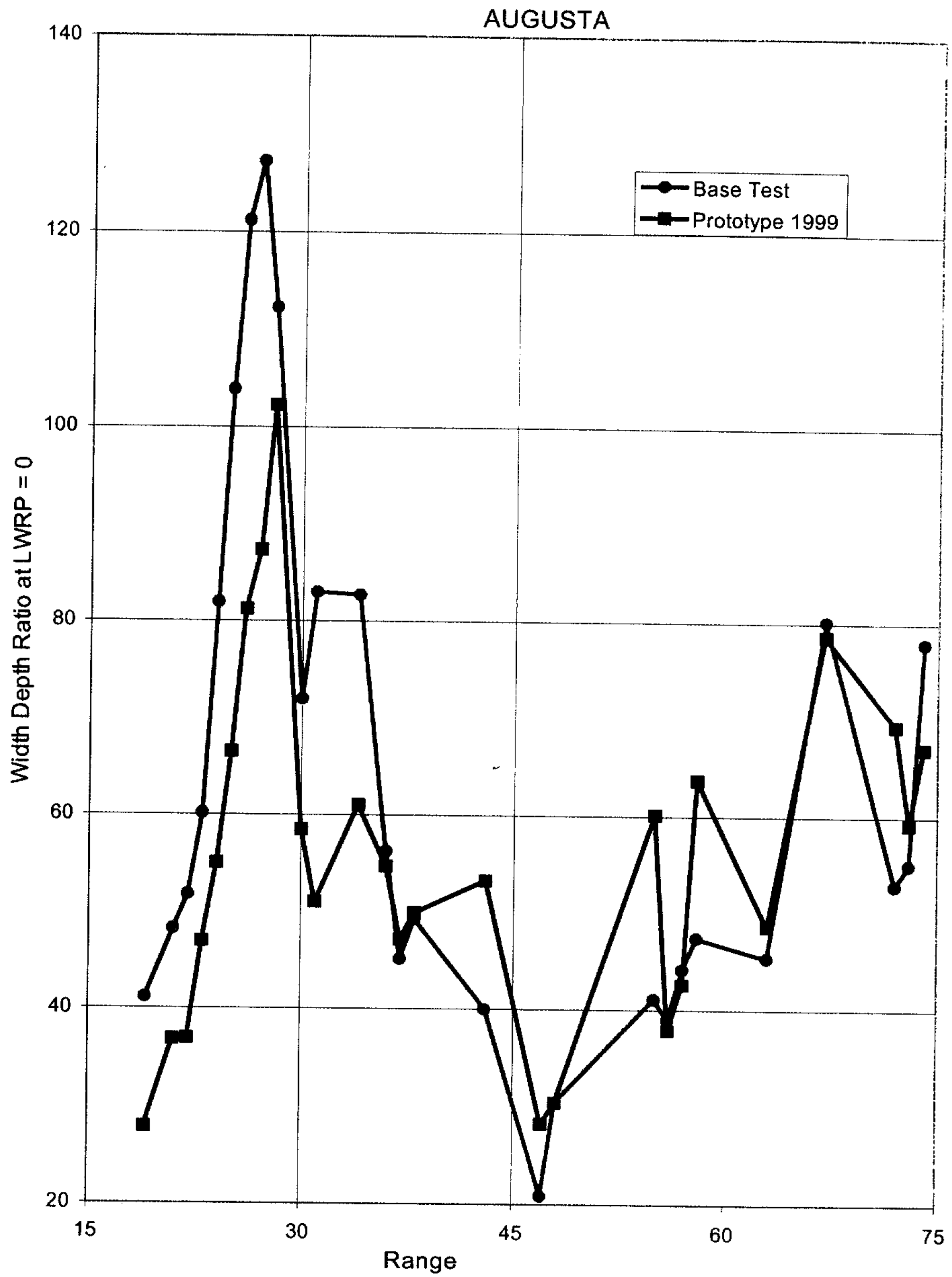

Figure C–1.2e Width/Depth Ratio by Range, Augusta (White River)

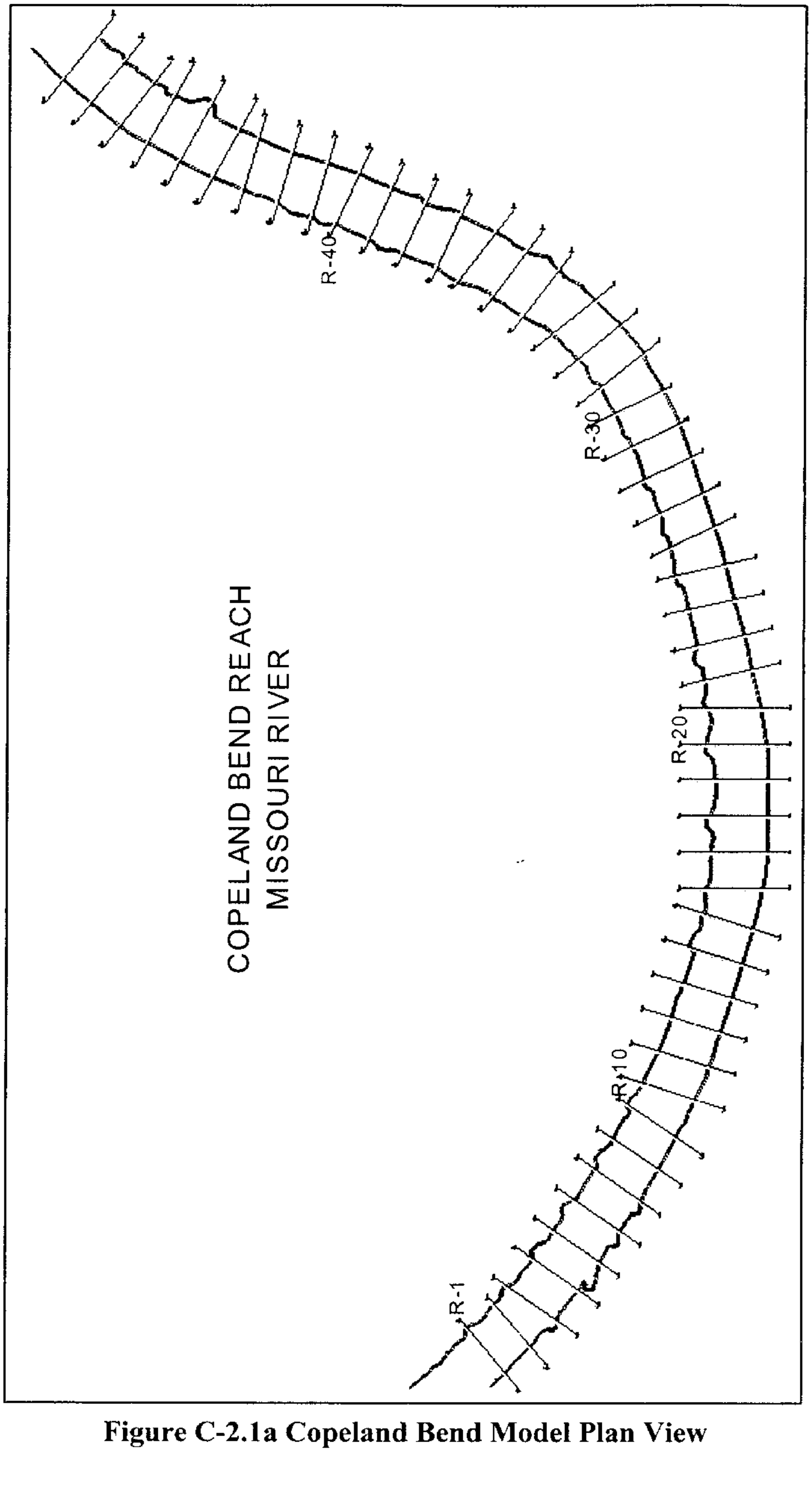

Figure C-2.1a Copeland Bend Model Plan View

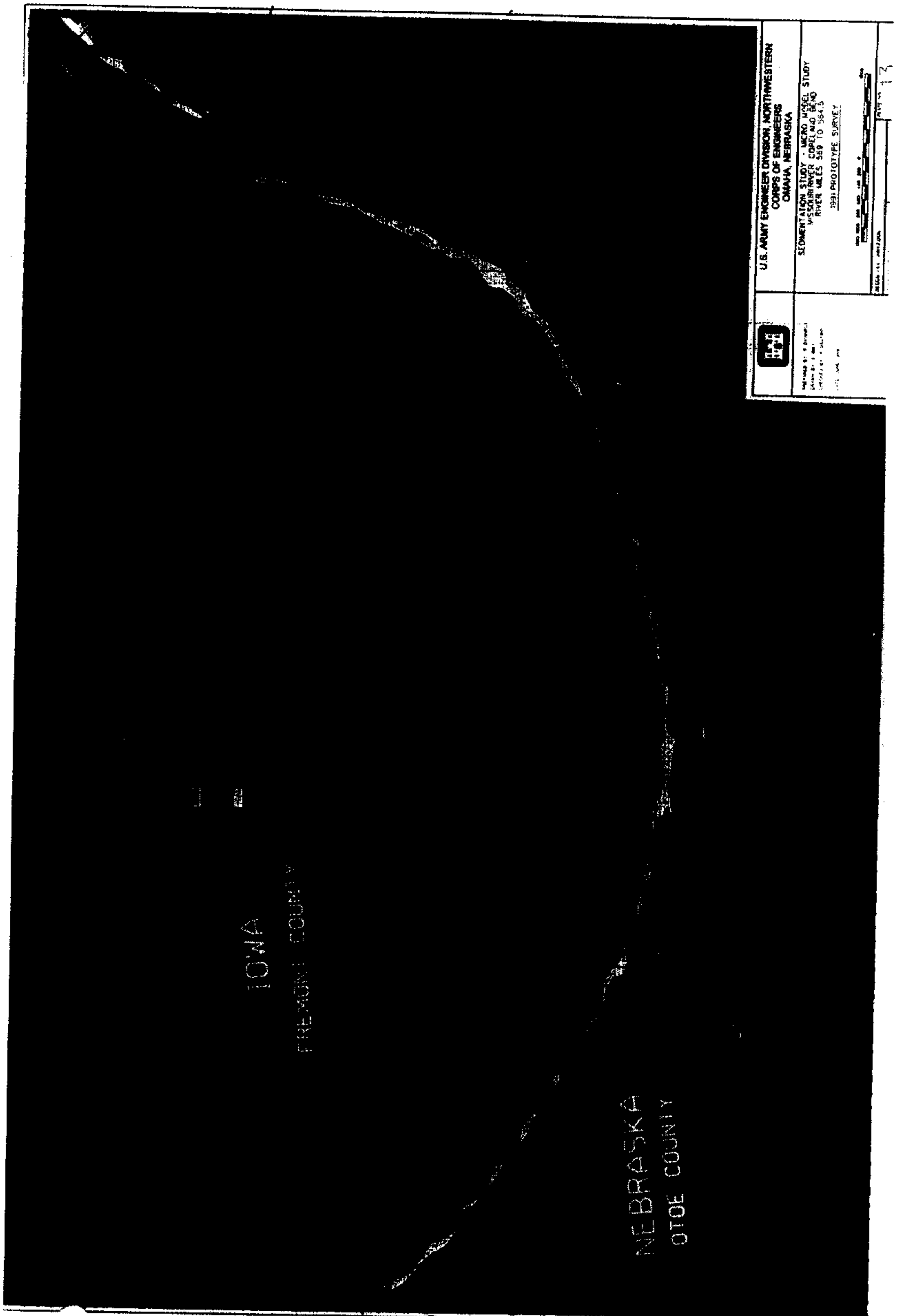

Figure C-2.1b 1991 Copeland Bend Prototype Survey

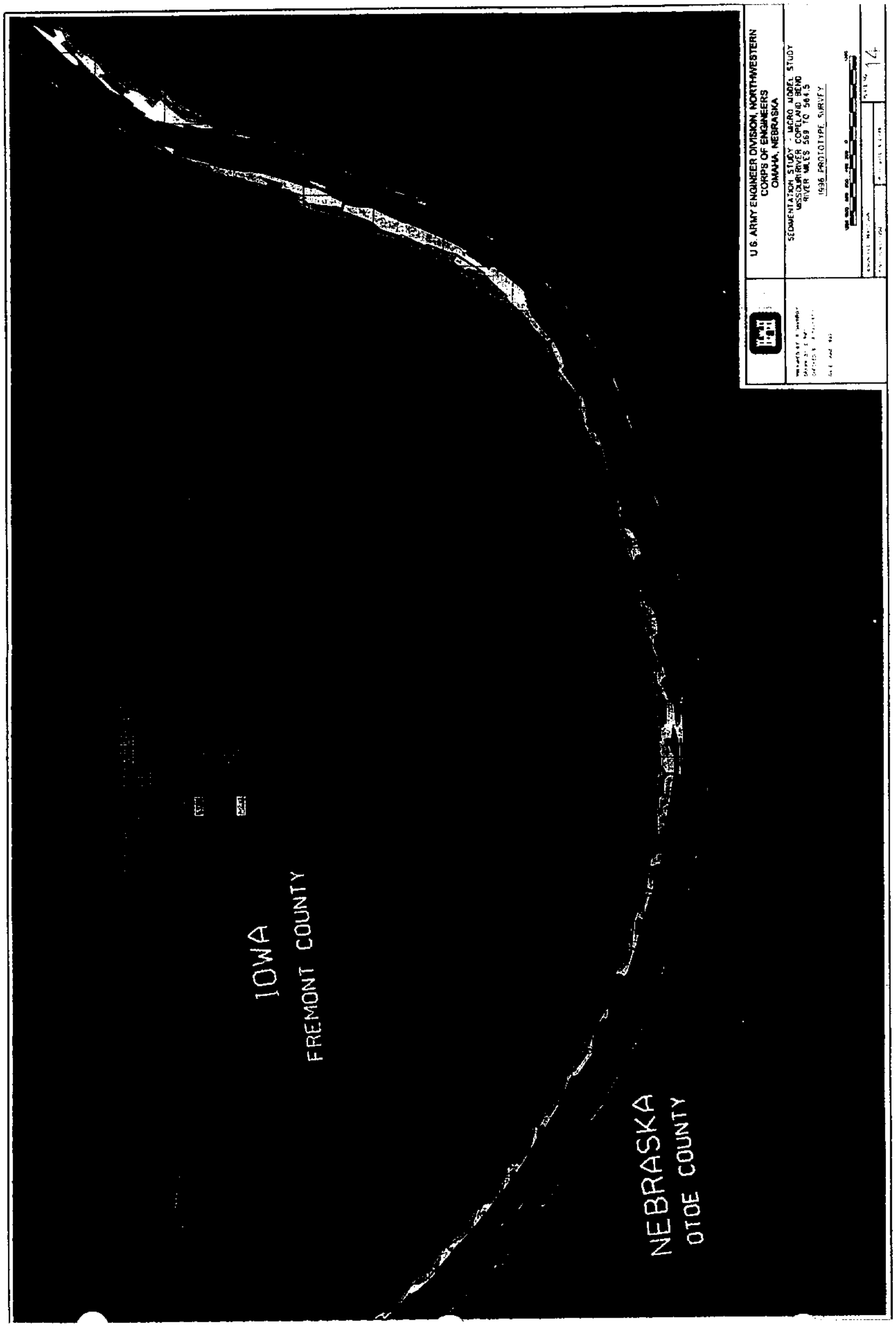

Figure C-2.1c 1996 Copeland Bend Prototype Survey

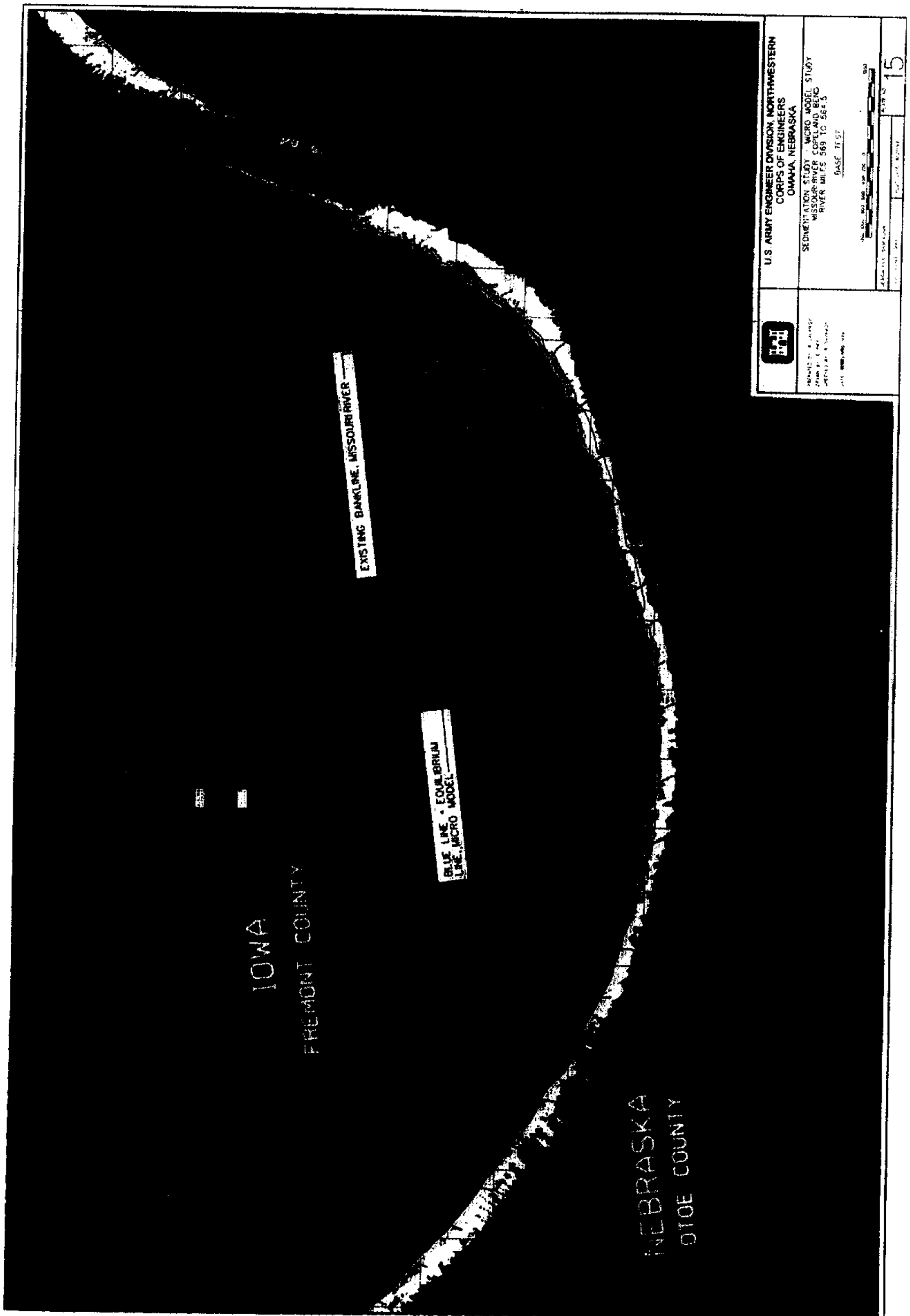

Figure C-2.1d Copeland Bend Micromodel Base Test

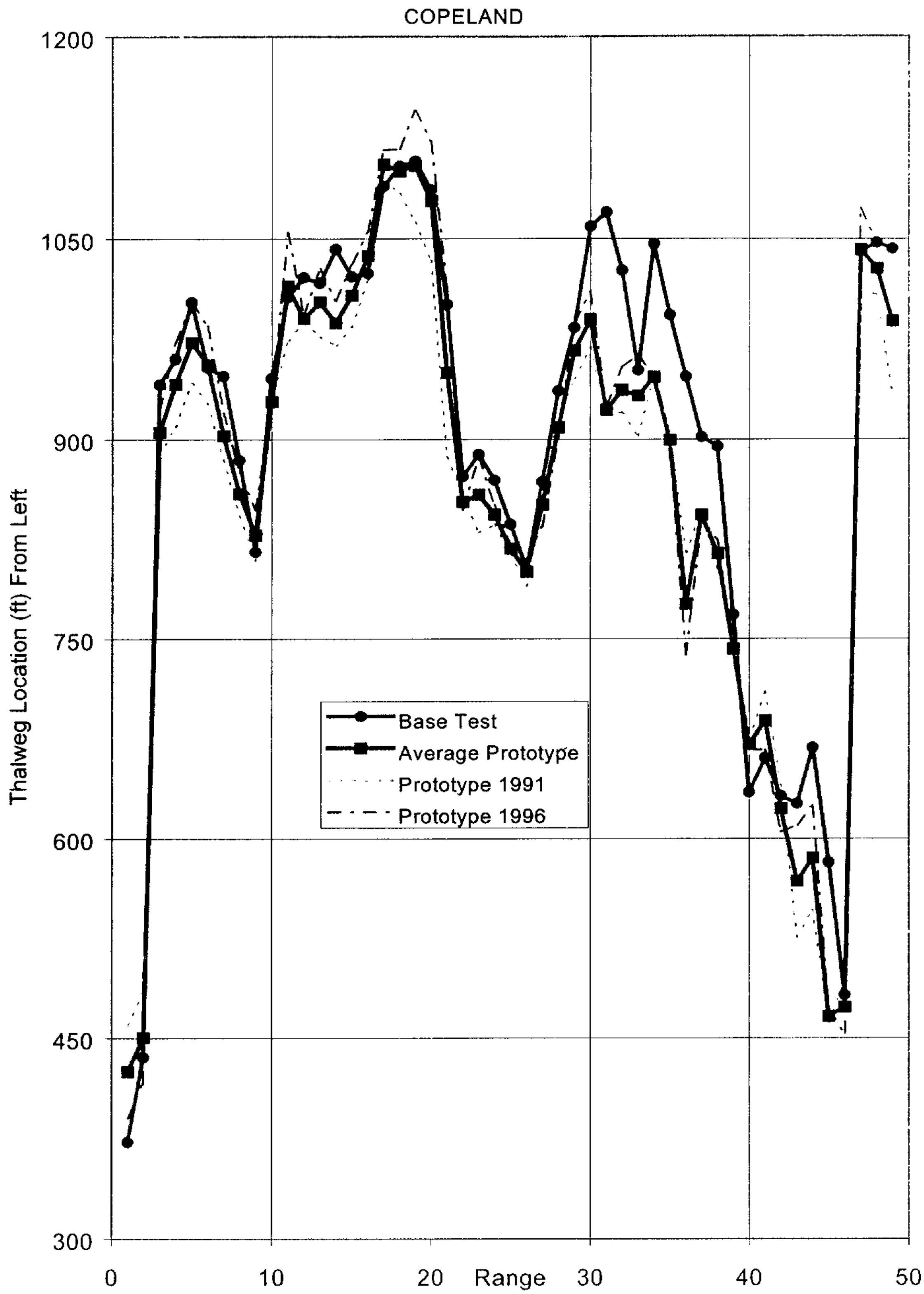

Figure C-2.2a Thalweg Distance From Left by Range, Copeland Bend (Mississippi River)

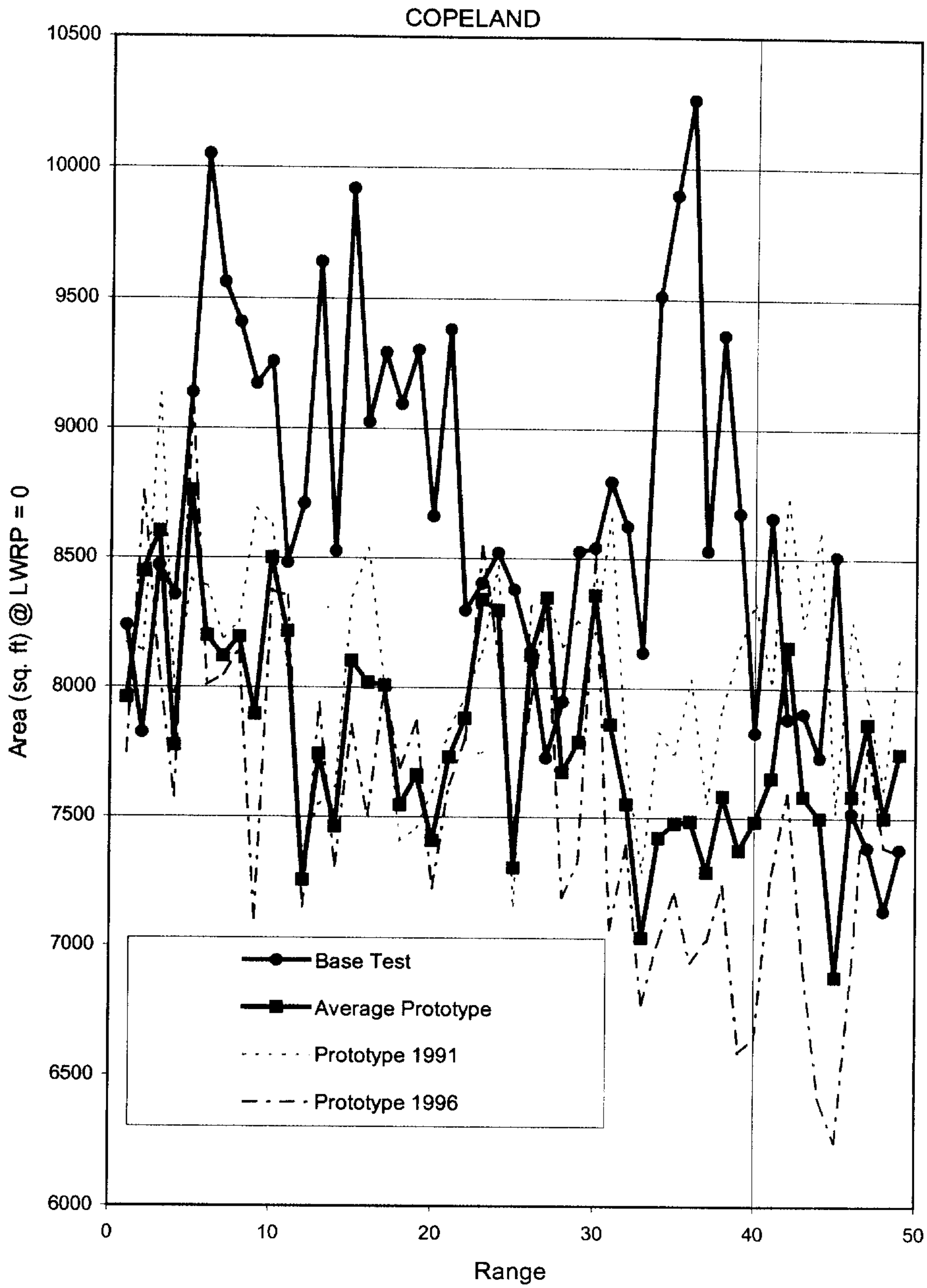

Figure C-2.2b Cross-Section Area by Range, Copeland Bend (Mississippi River)

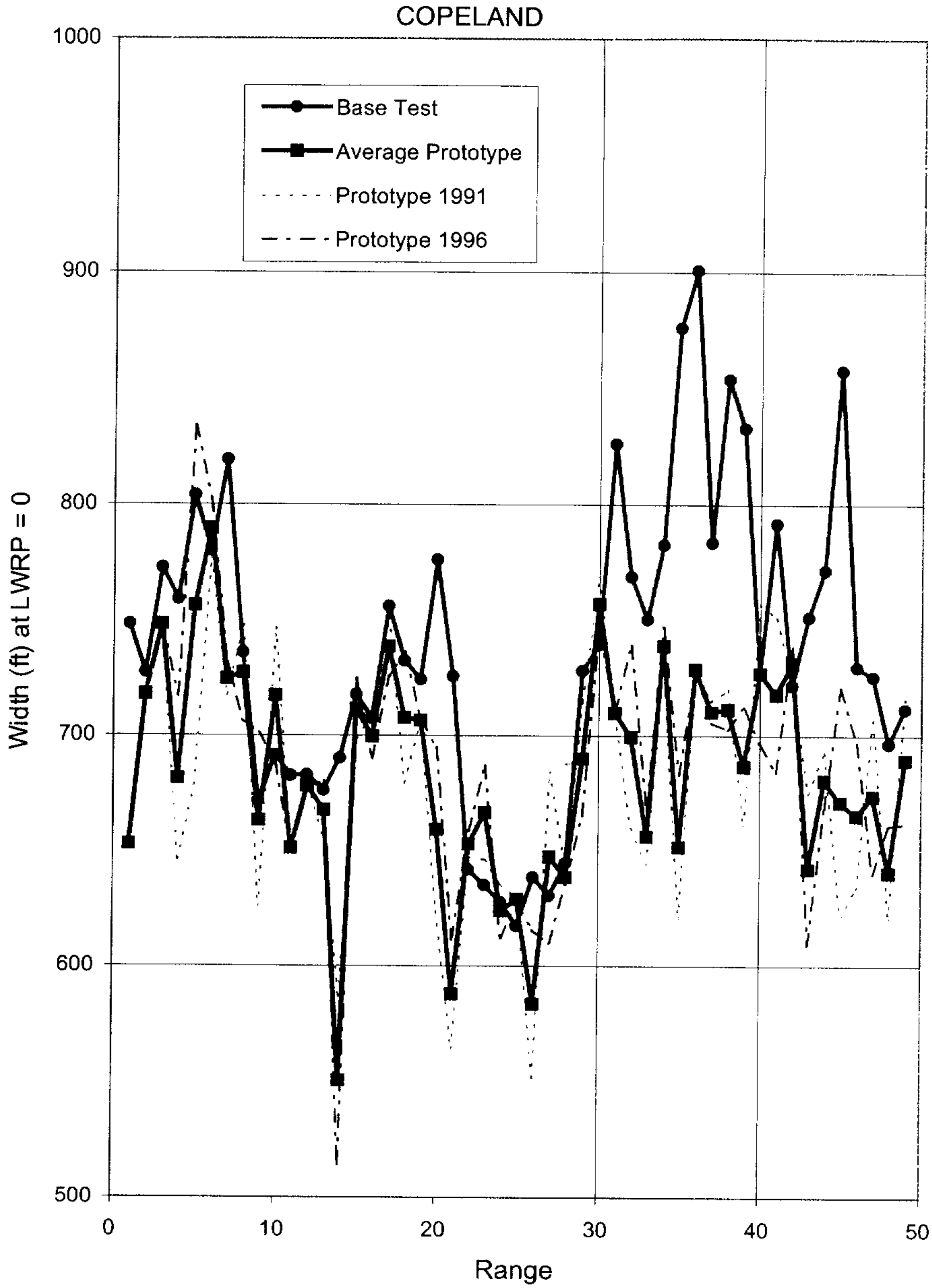

Figure C-2.2c Top Width by Range, Copeland Bend (Mississippi River)

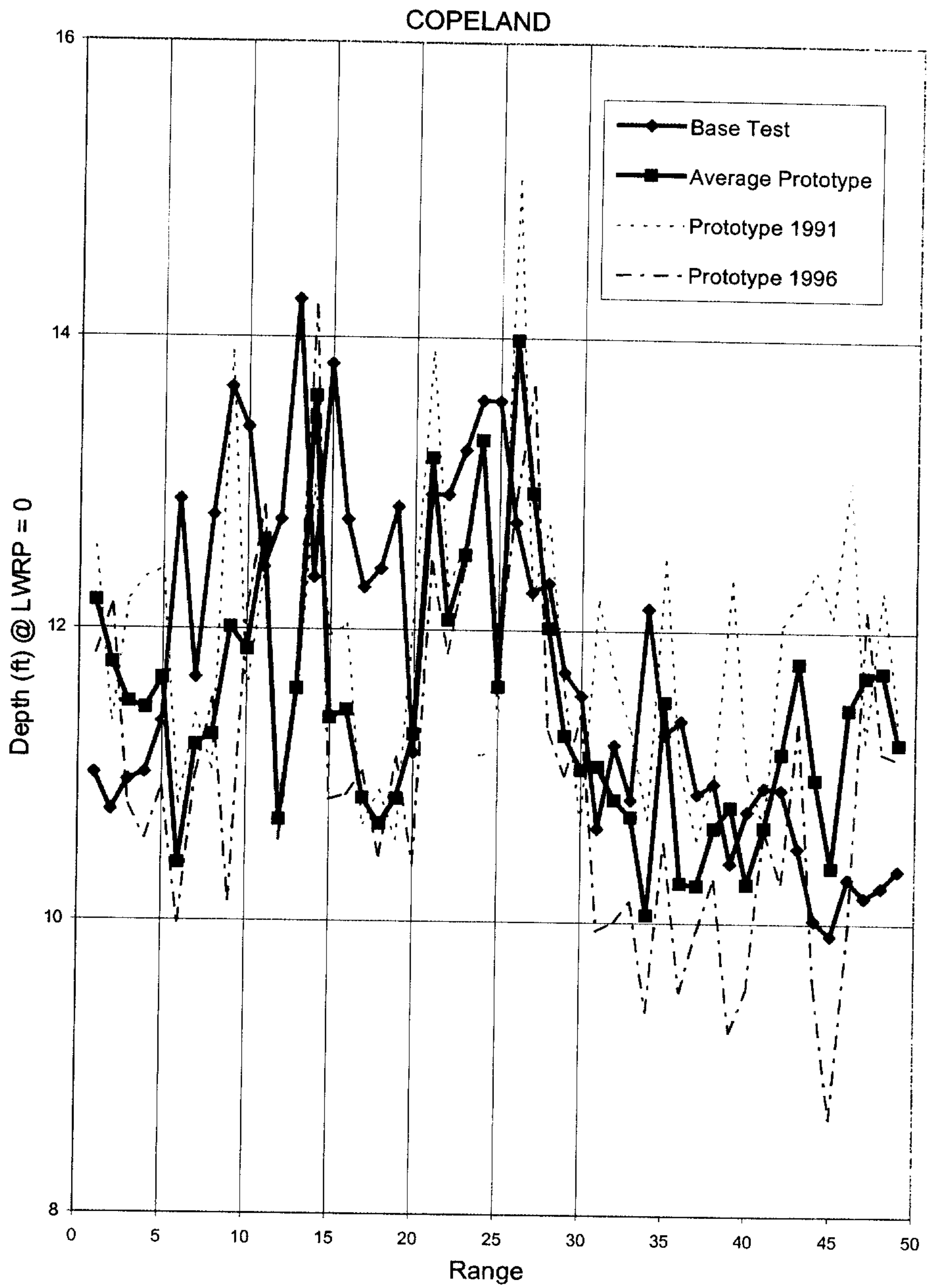

Figure C-2.2d Hydraulic Depth by Range, Copeland Bend (Mississippi River)

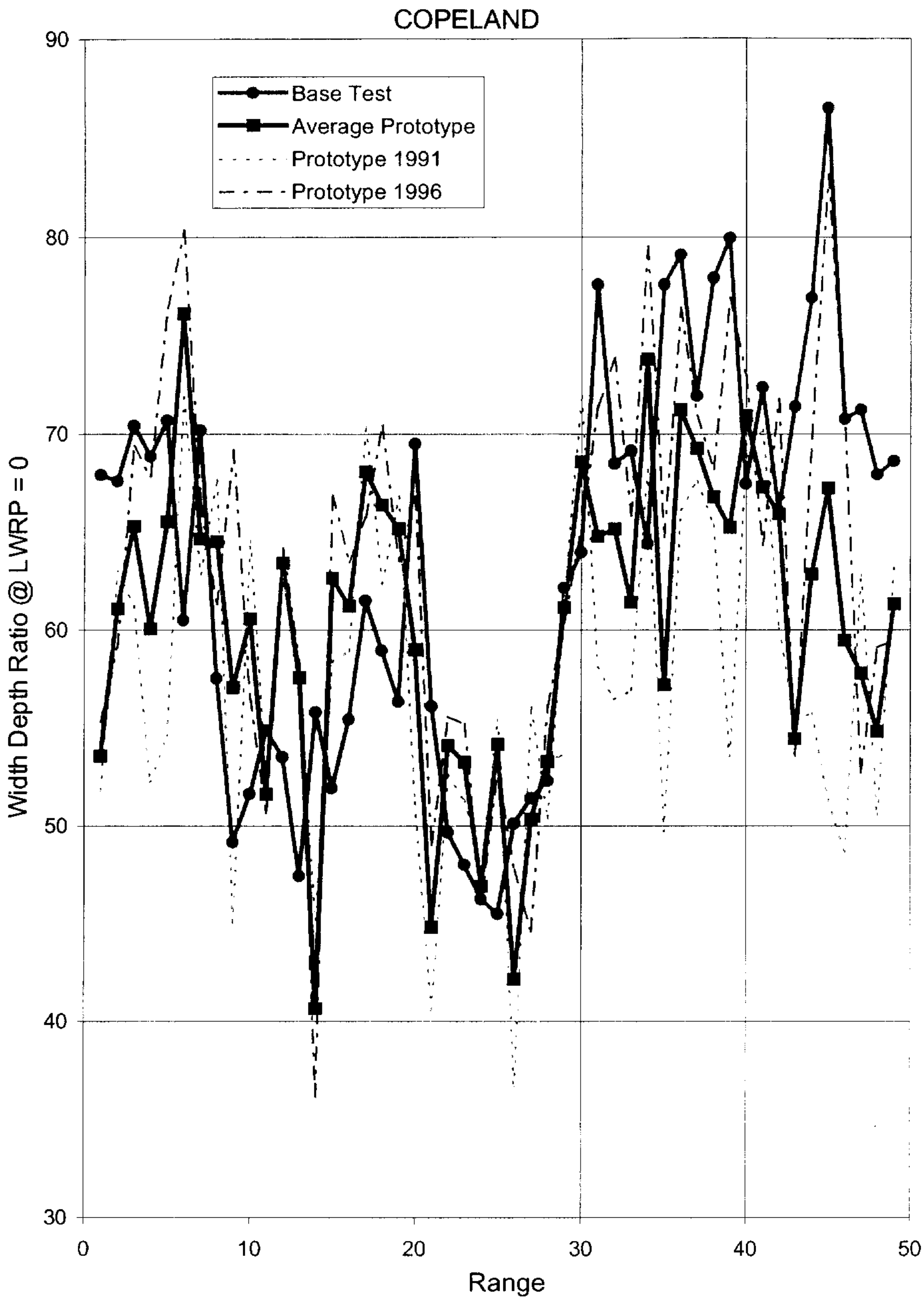

Figure C-2.2e Width/Depth Ratio by Range, Copeland Bend (Mississippi River)

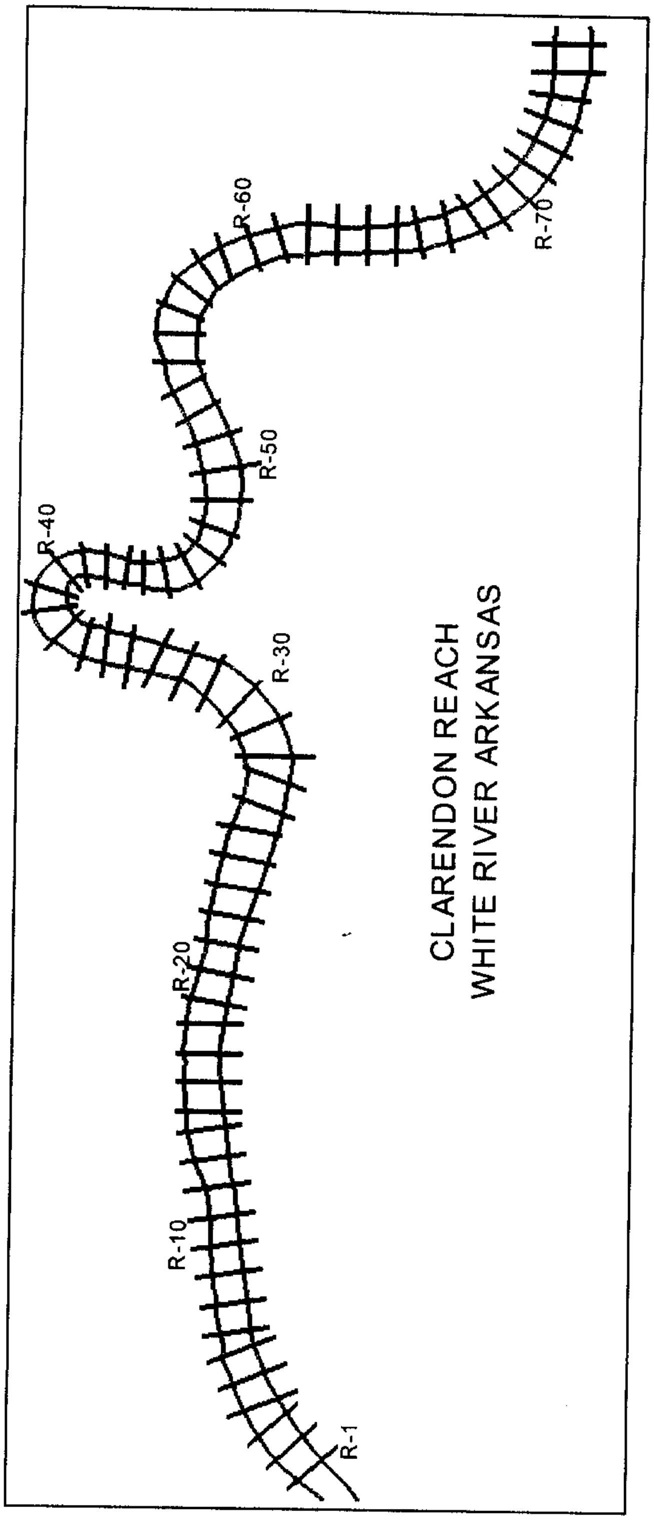

Figure C-3.1a Clarendon Model Plan View

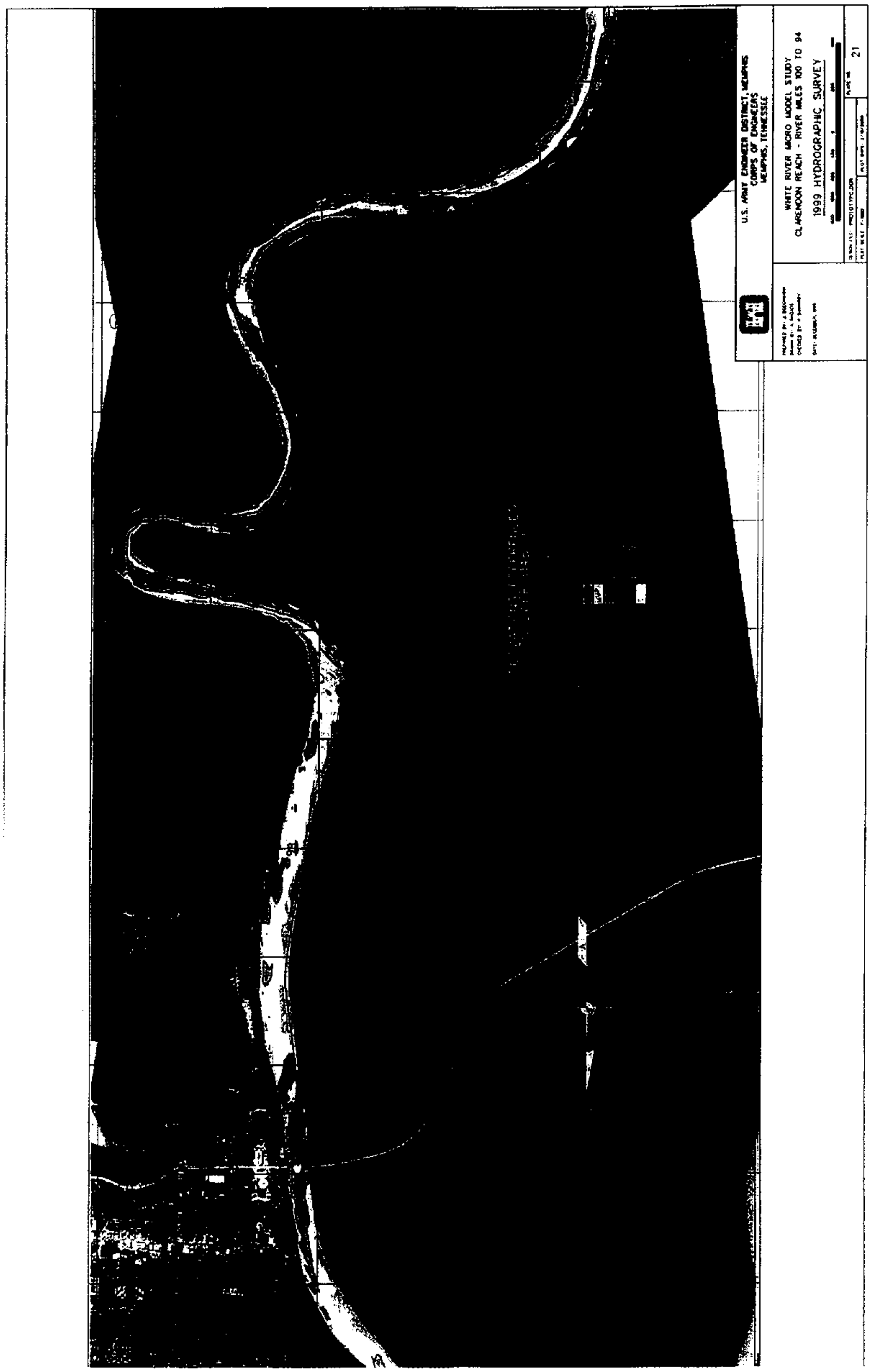

Figure C-3.1b 1999 Clarendon Prototype Survey

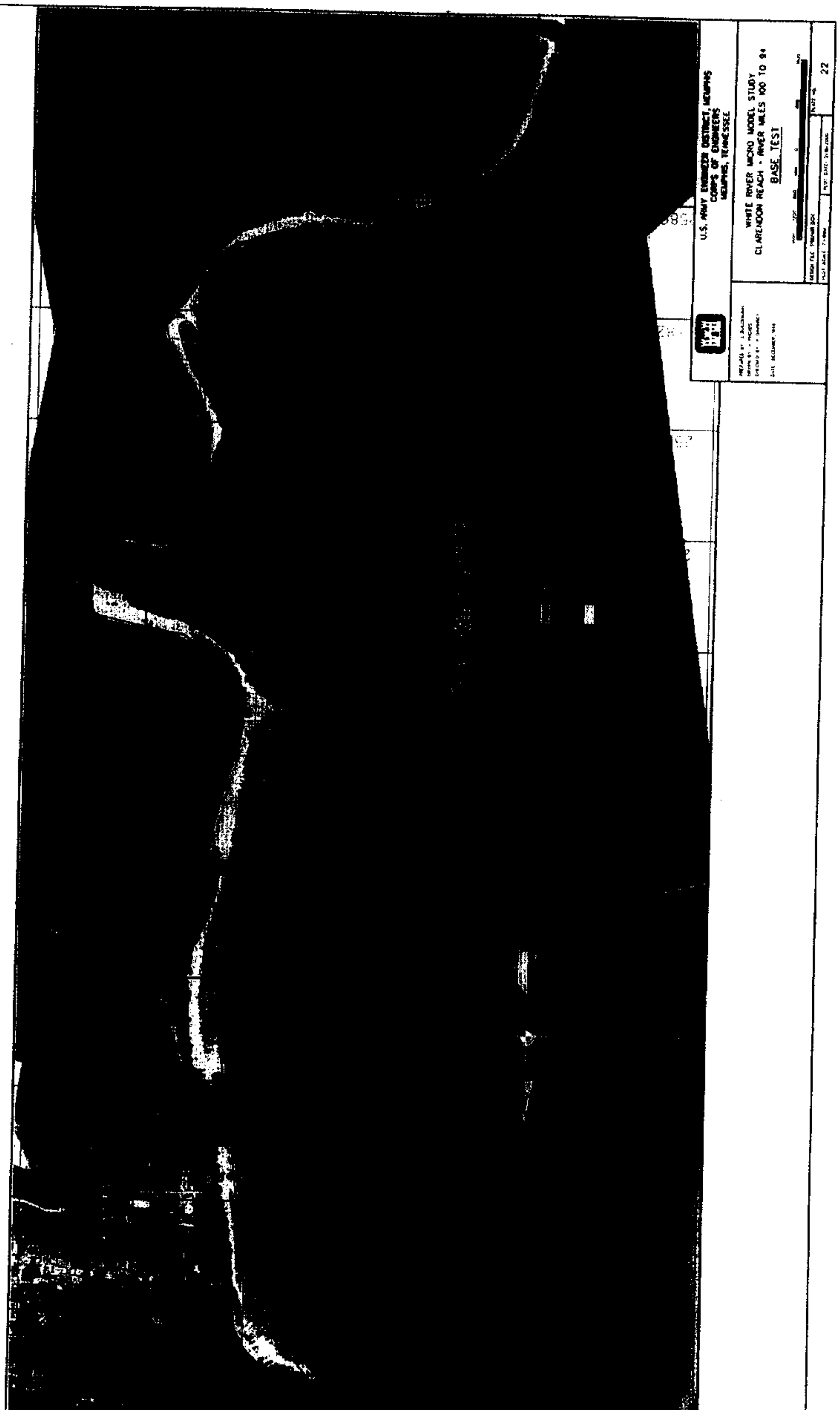

Figure C-3.1c Clarendon Micromodel Base Test

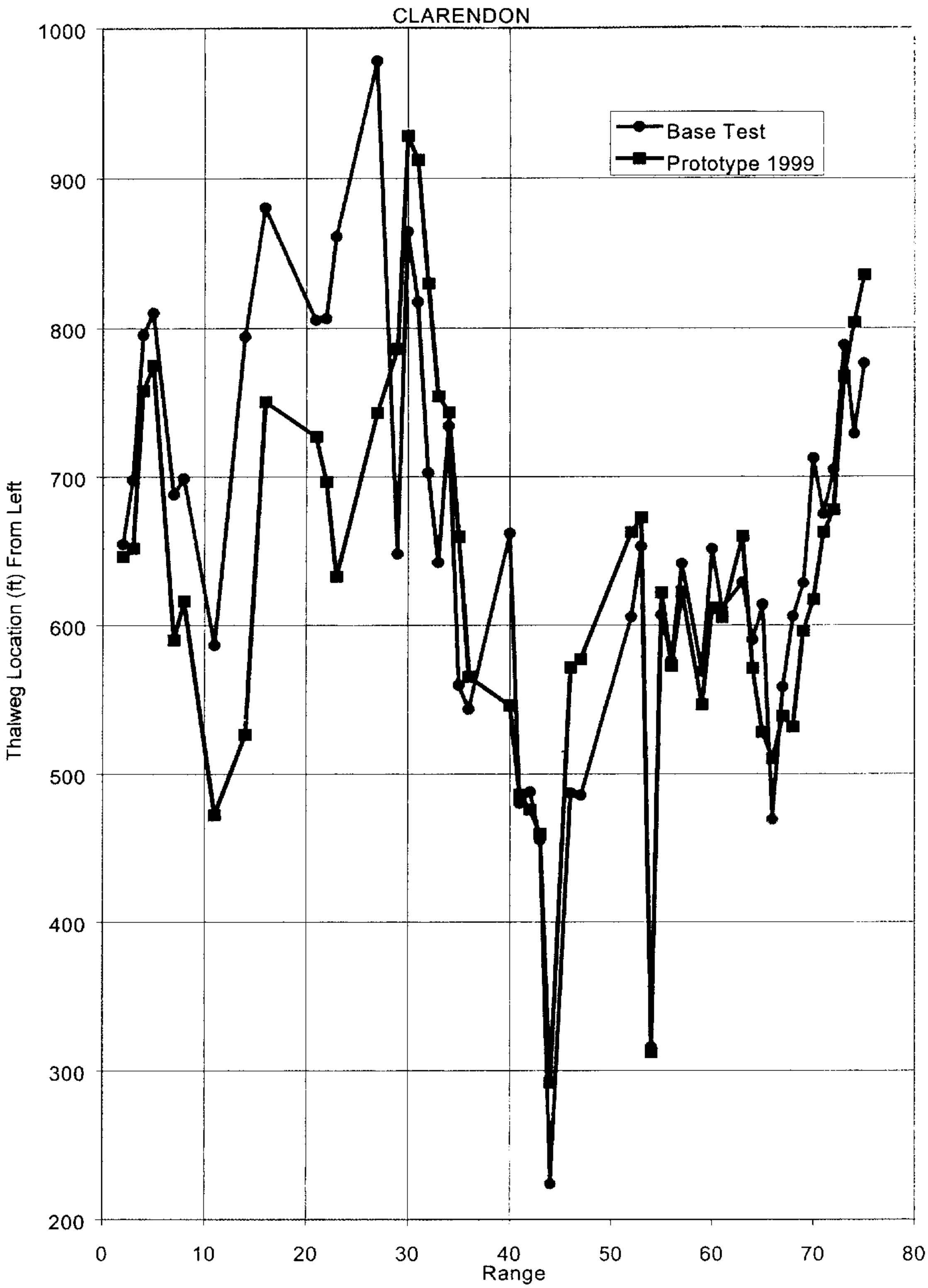

Figure C-3.2a Thalweg From Left by Range, Clarendon Reach (White River)

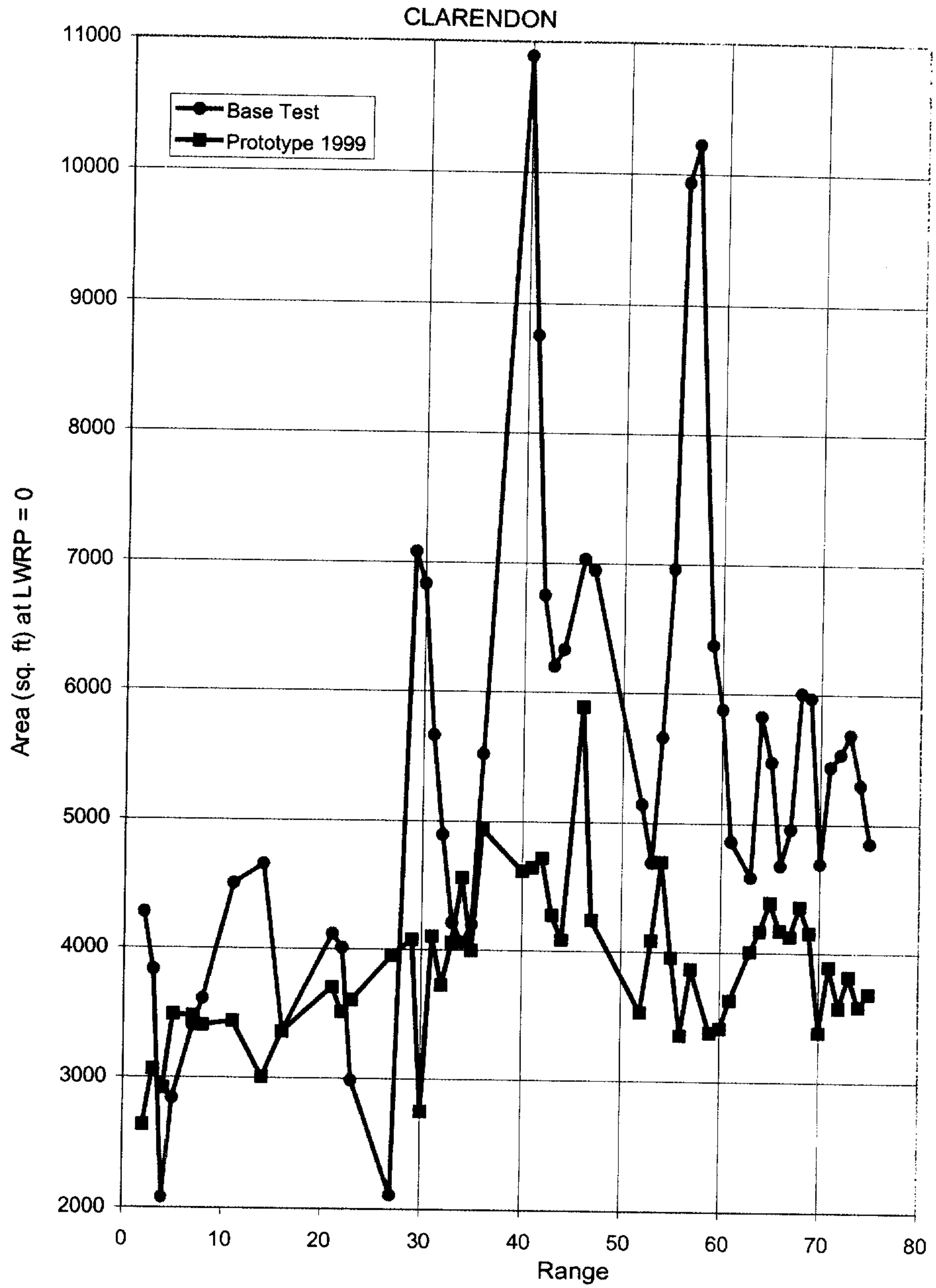

Figure C-3.2b Cross-Section Area by Range, Clarendon Reach (White River)

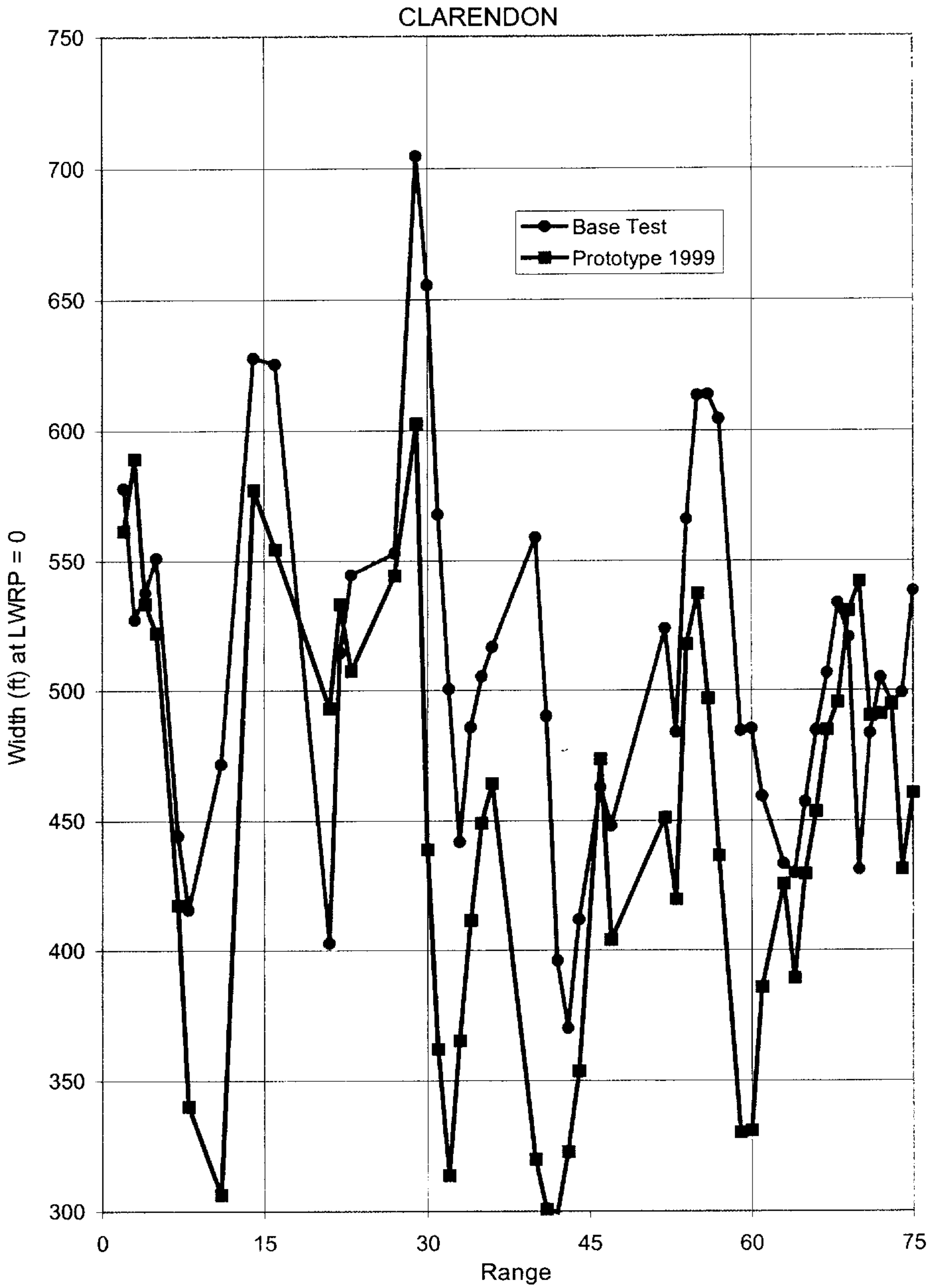

Figure C-3.2c Top Width by Range, Clarendon Reach (White River)

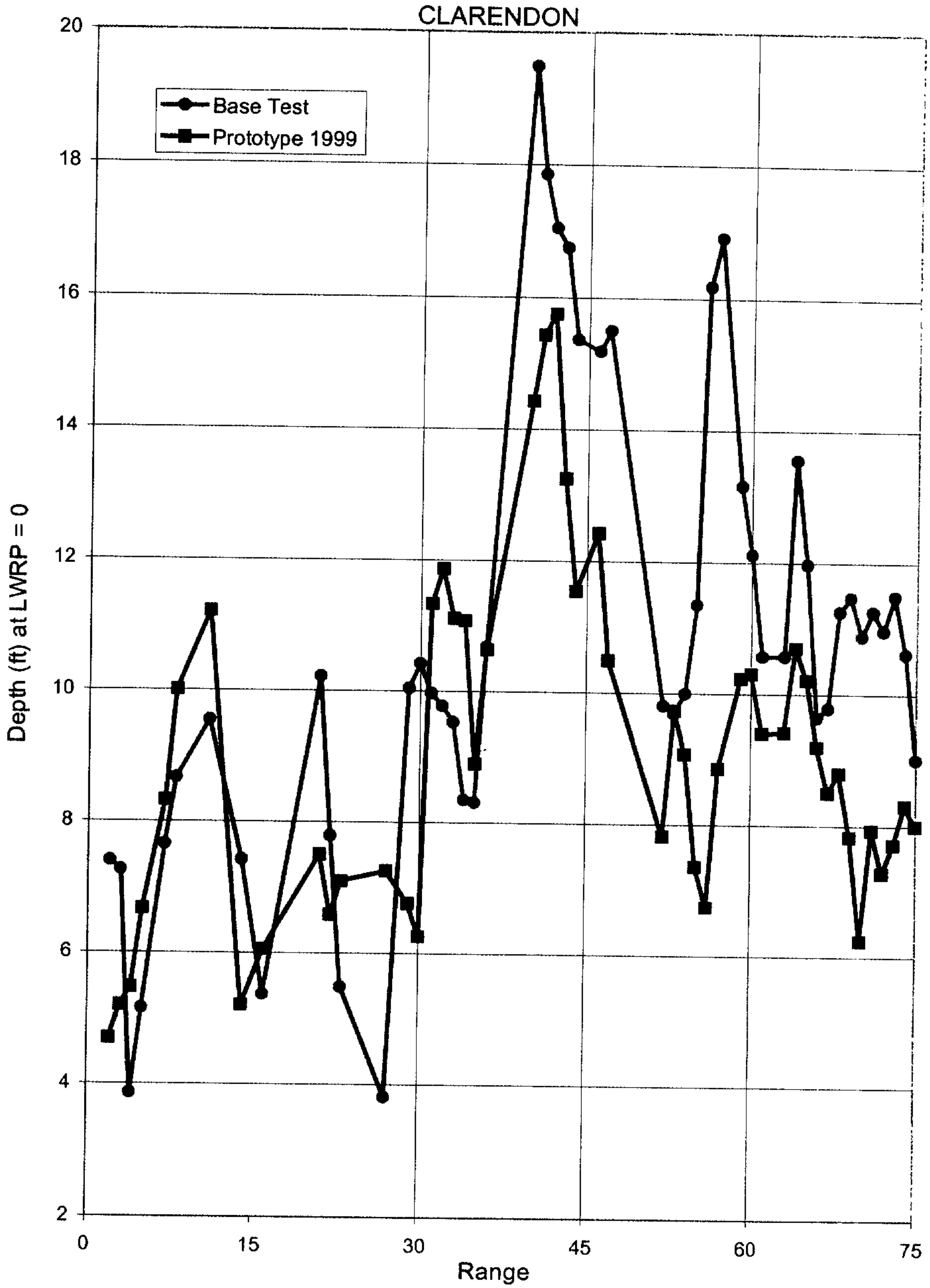

Figure C-3.2d Hydraulic Depth by Range, Clarendon Reach (White River)

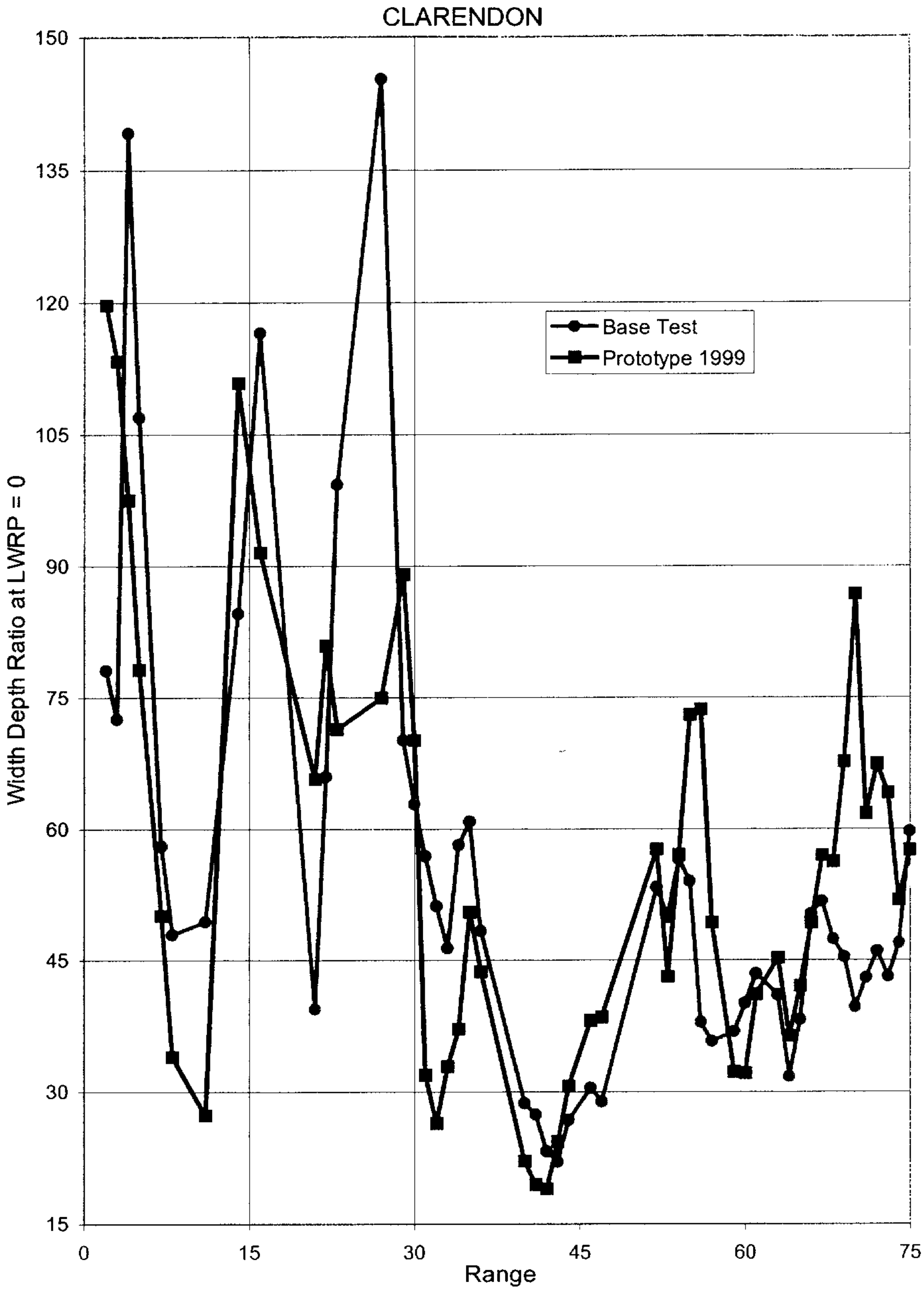

Figure C-3.2e Width/Depth Ratio by Range, Clarendon Reach (White River)

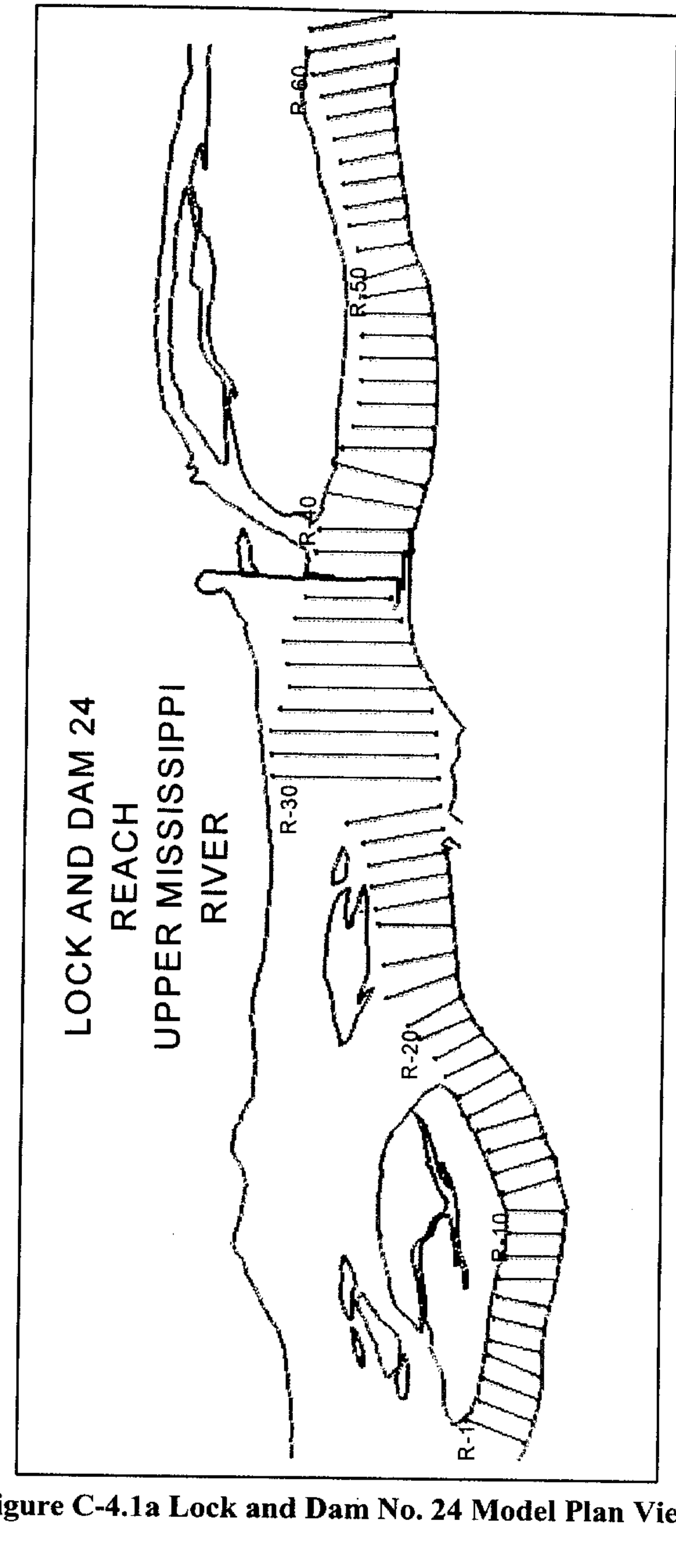

Figure C-4.1a Lock and Dam No. 24 Model Plan View

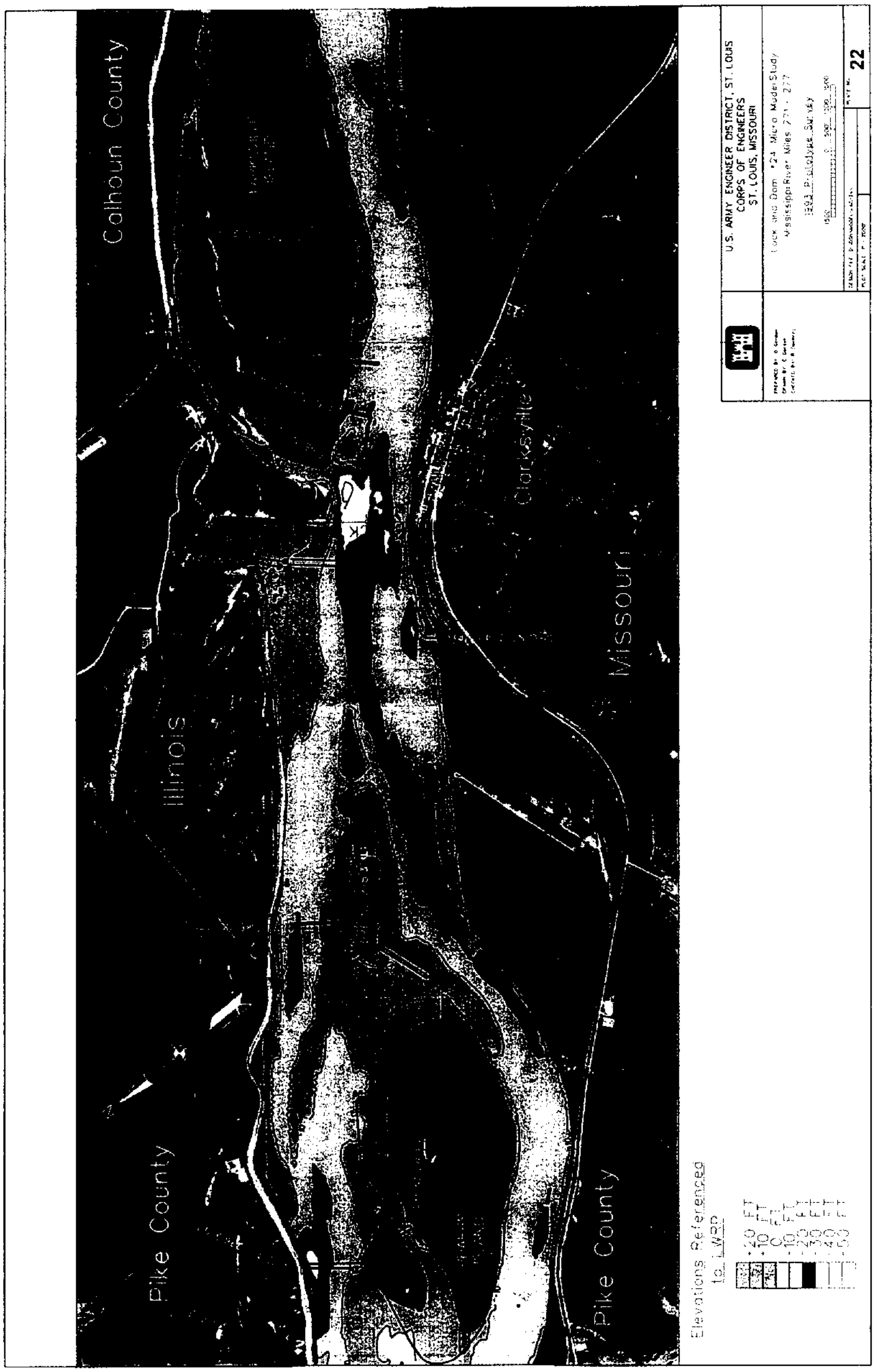

Figure C-4.1b Lock and Dam No. 24 1993 Prototype Survey

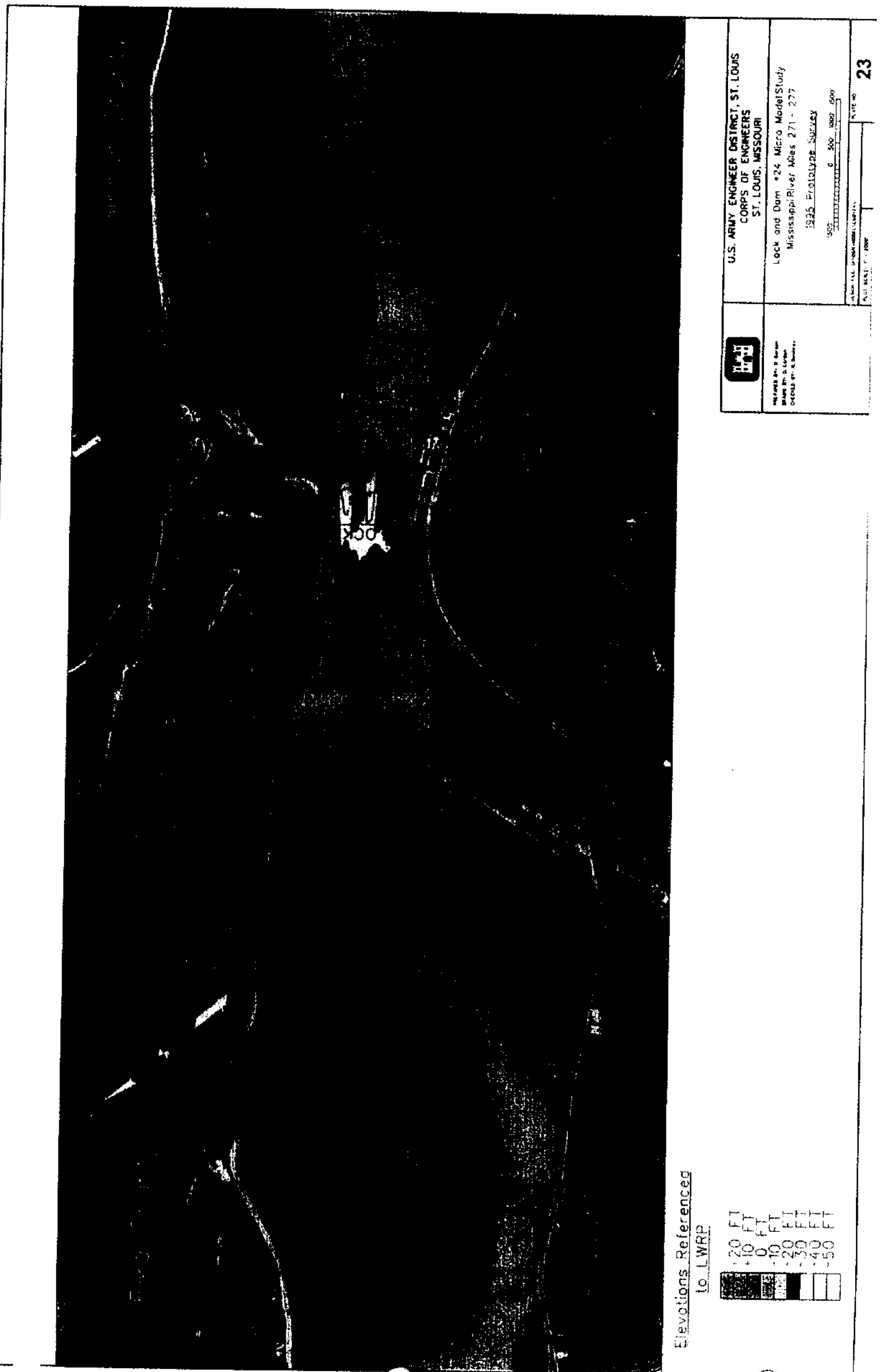

Figure C-4.1c Lock and Dam No. 24 1995 Prototype Survey

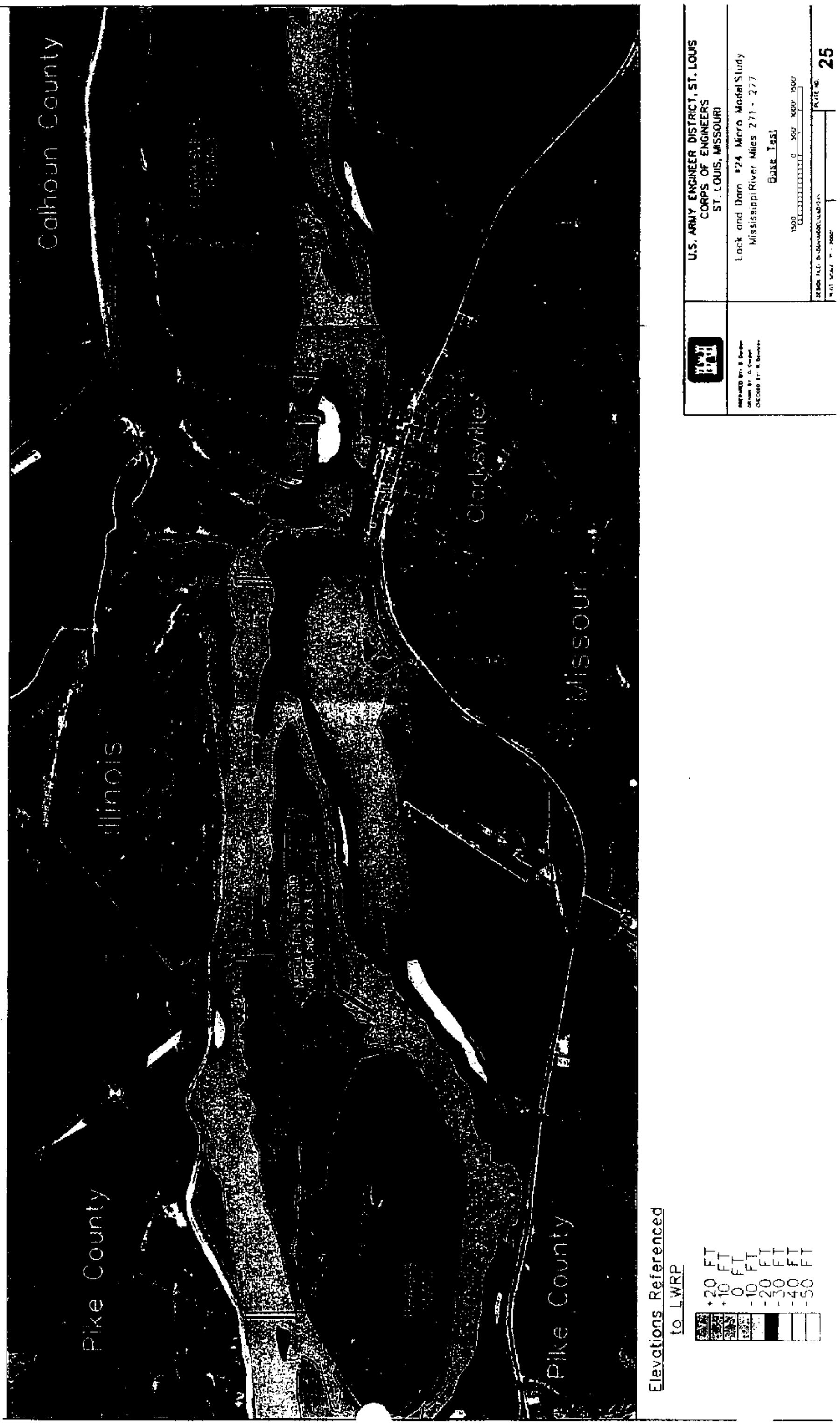

Figure C-4.1d Lock and Dam No. 24 Micromodel Base Test

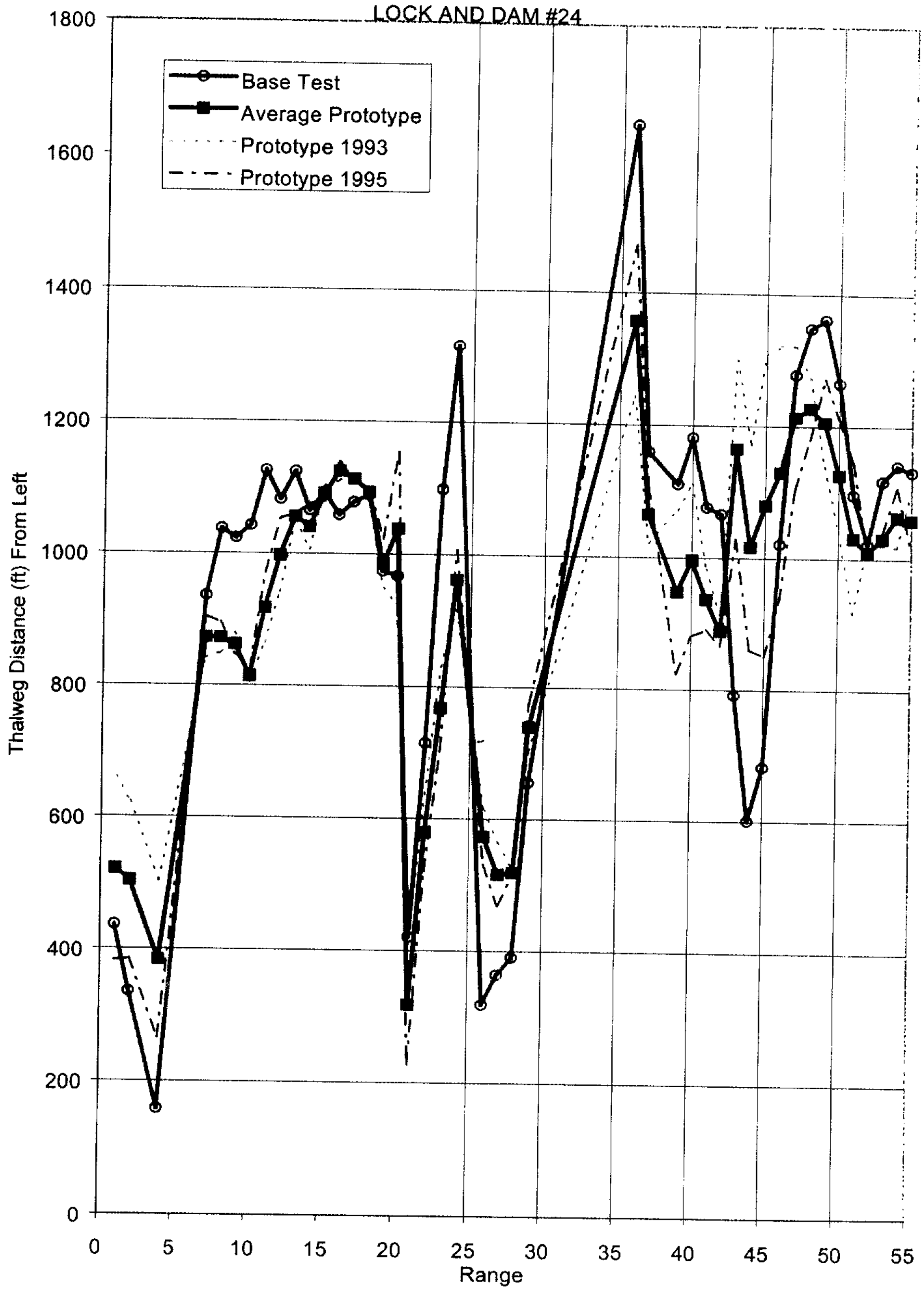

Figure C-4.2a Lock and Dam No. 24 Thalweg Position From Left, L and D 24 (Mississippi River)

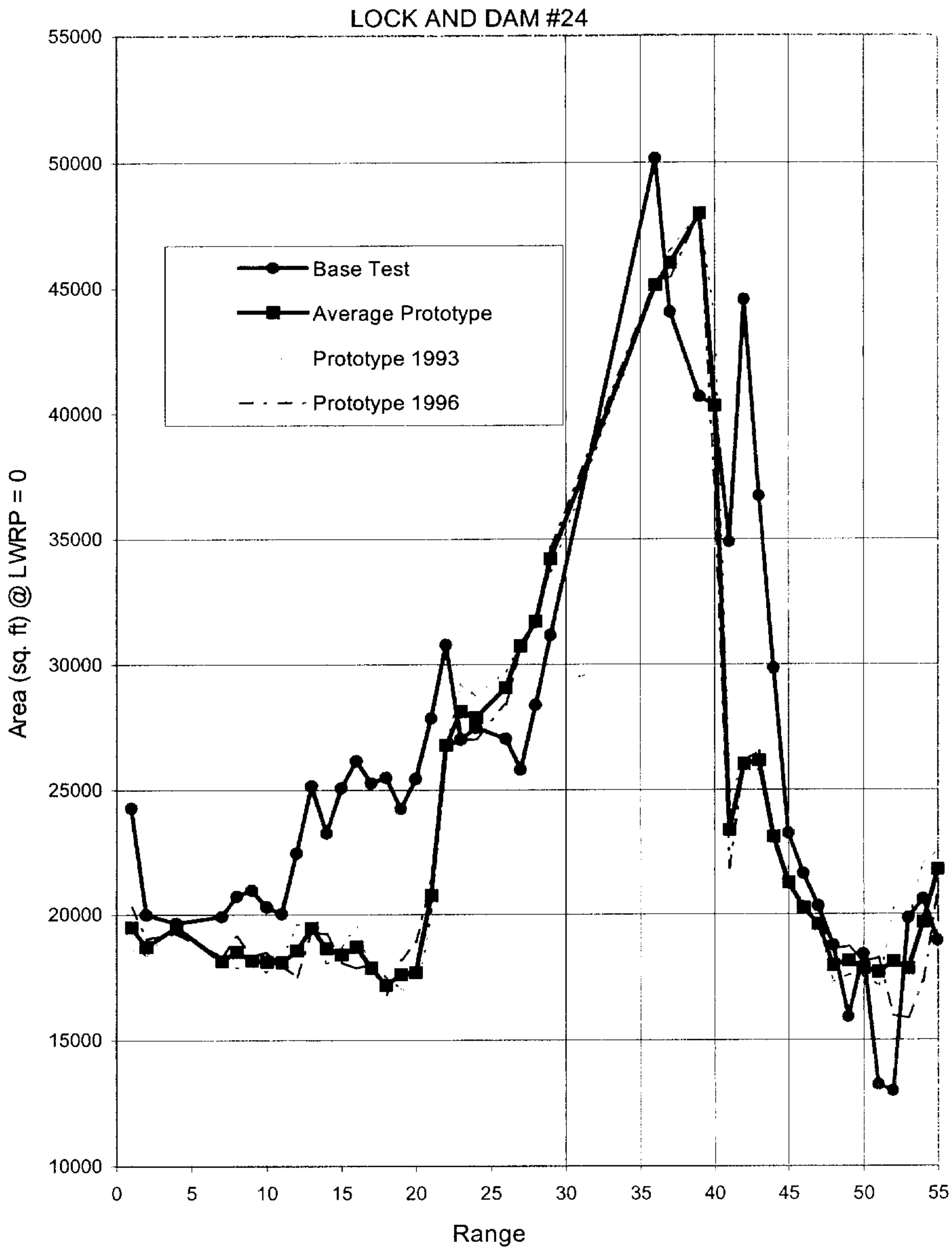

Figure C-4.2b Cross-Section Area by Range, Lock and Dam No. 24 (Mississippi River)

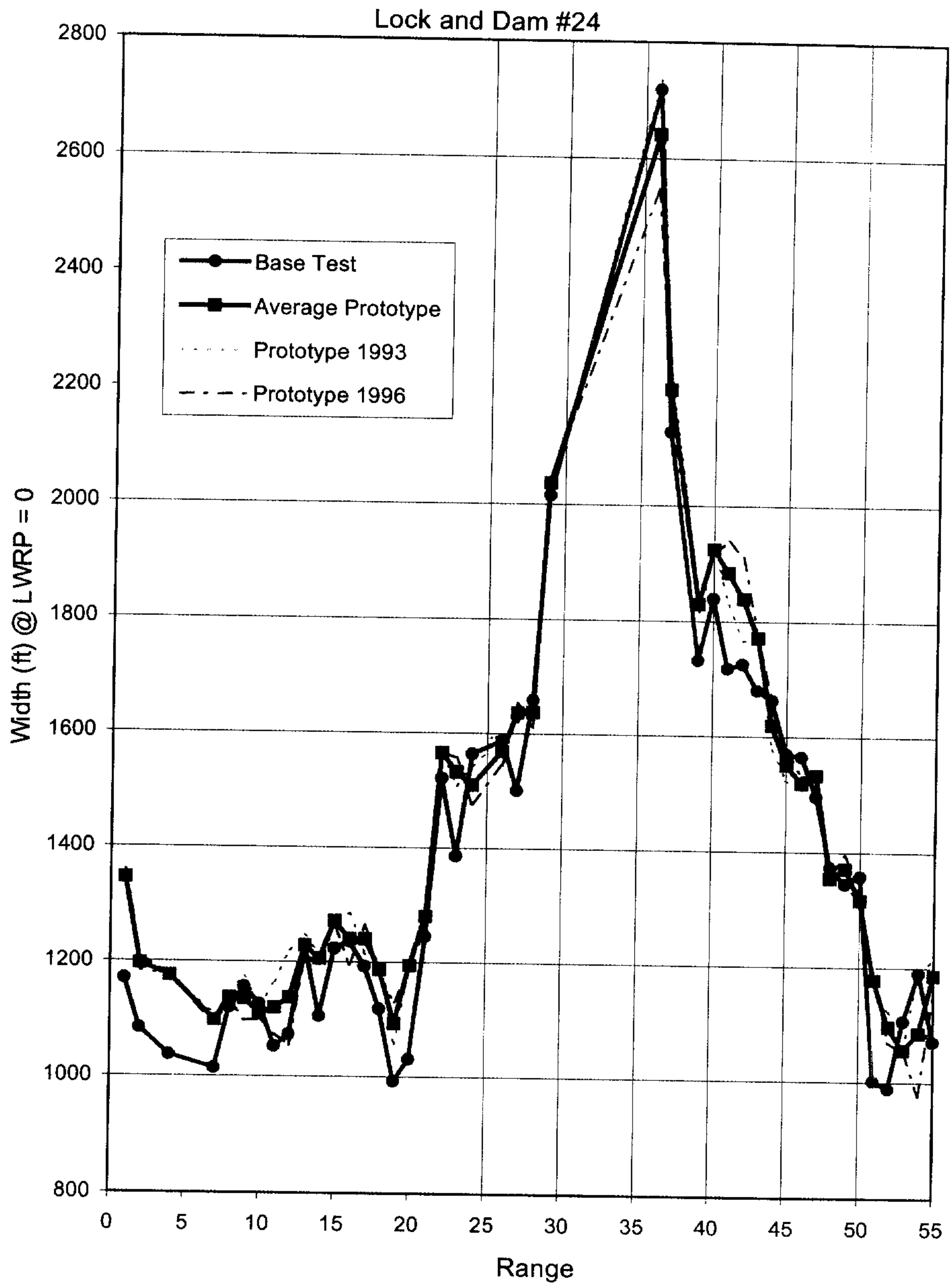

Figure C-4.2c Top Width by Range, Lock and Dam No. 24 (Mississippi River)

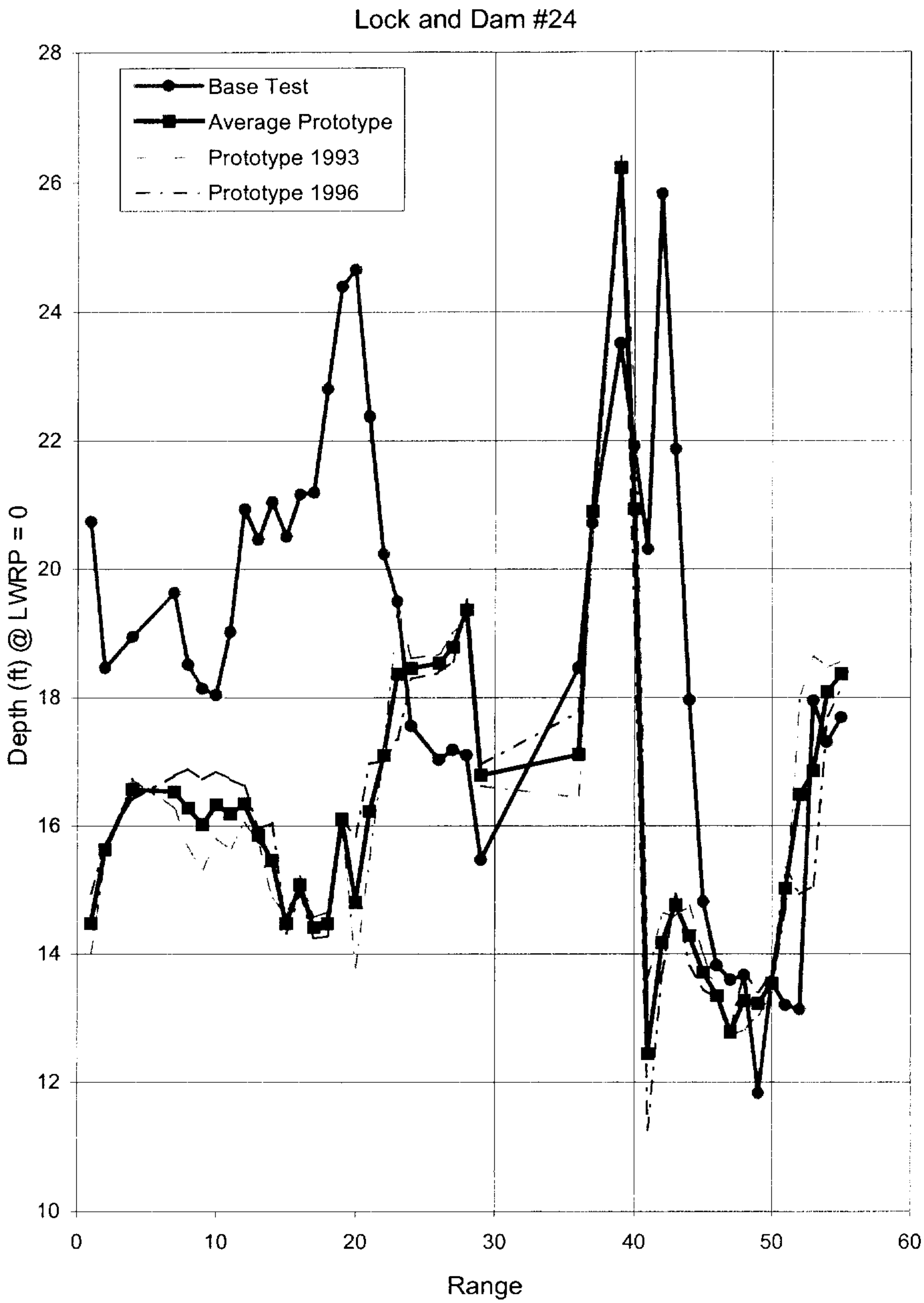

Figure C-4.2d Hydraulic Depth by Range, Lock and Dam No. 24 (Mississippi River)

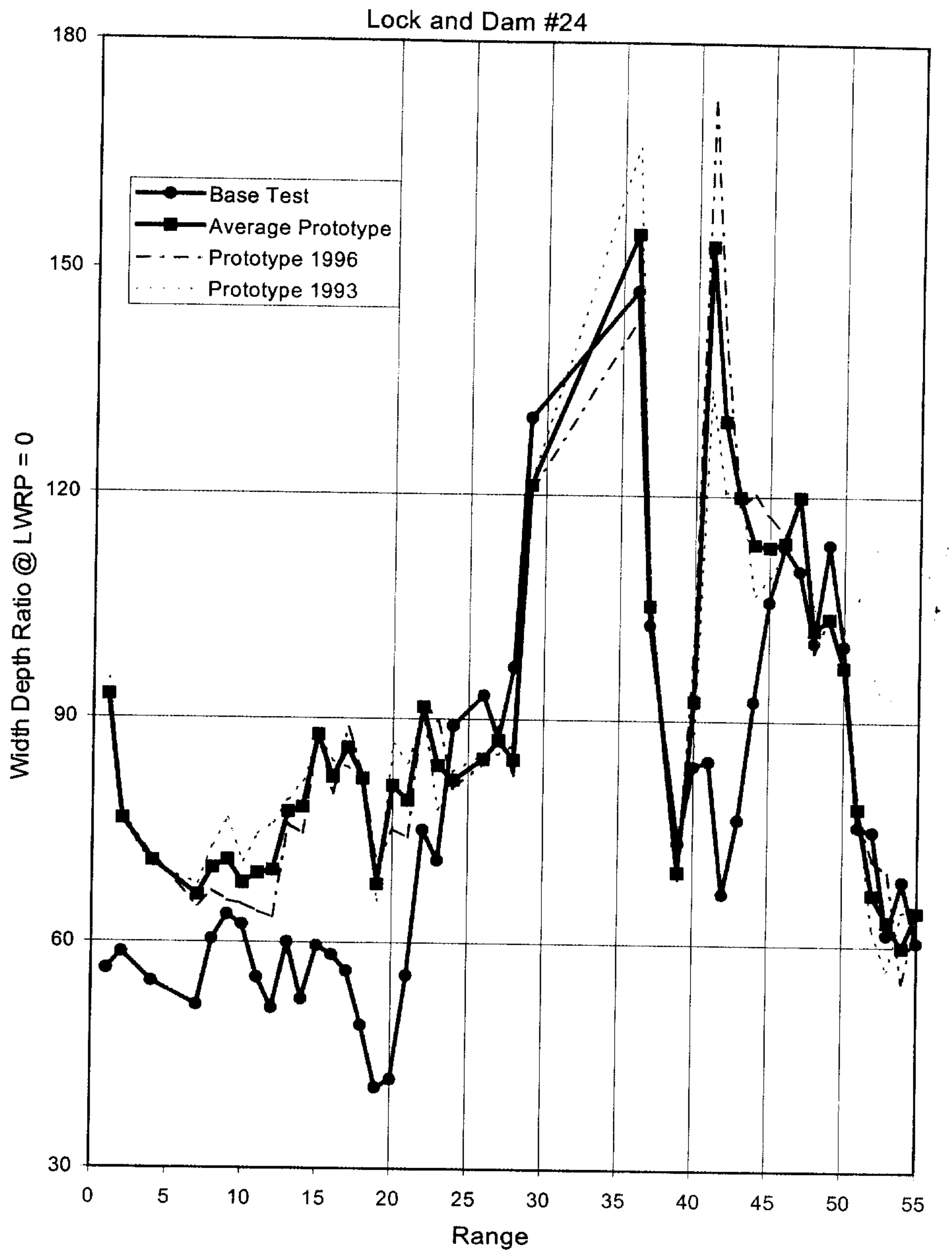

Figure C-4.2e Width/Depth Ratio by Range, Lock and Dam No. 24 (Mississippi River)

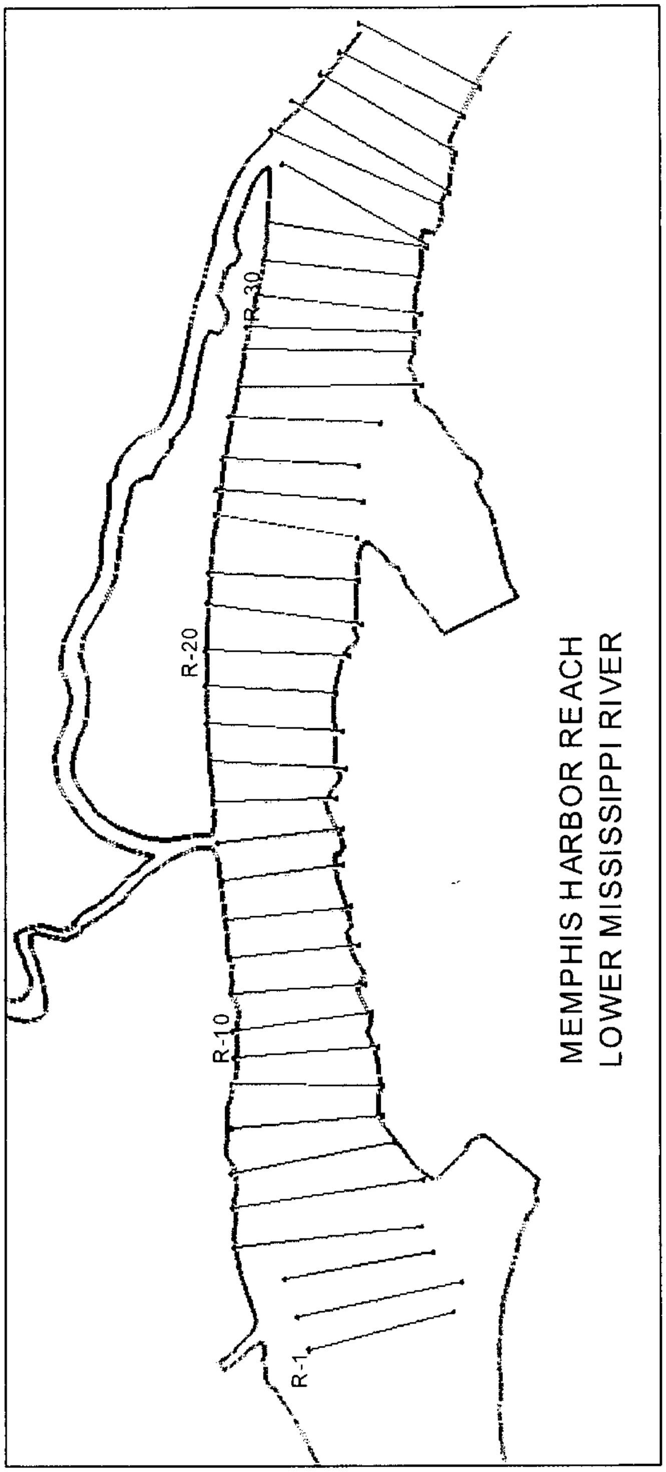

Figure C-5.1a Memphis Harbor Micromodel Plan View

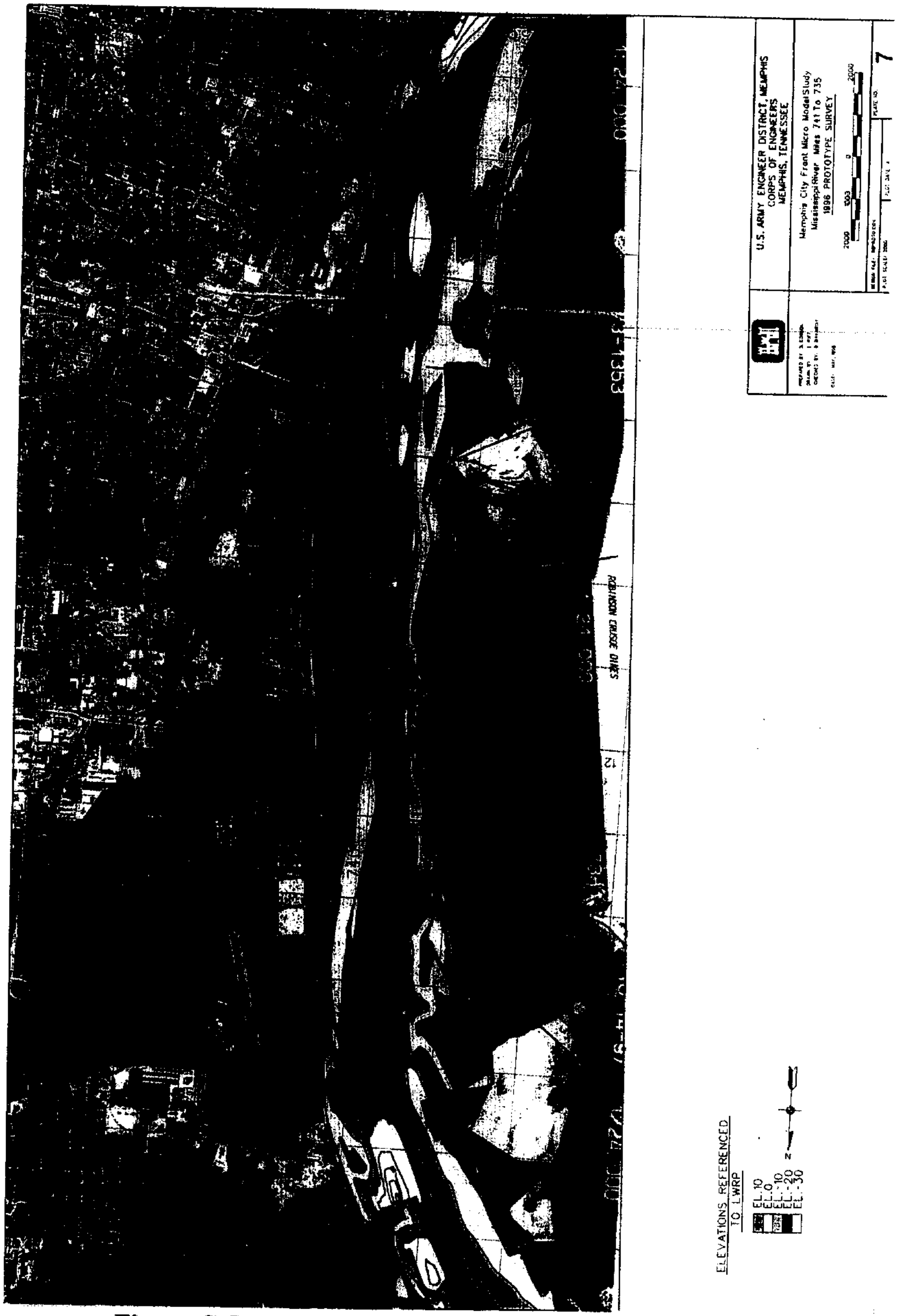

Figure C-5.1b Memphis Harbor Prototype Survey 1996

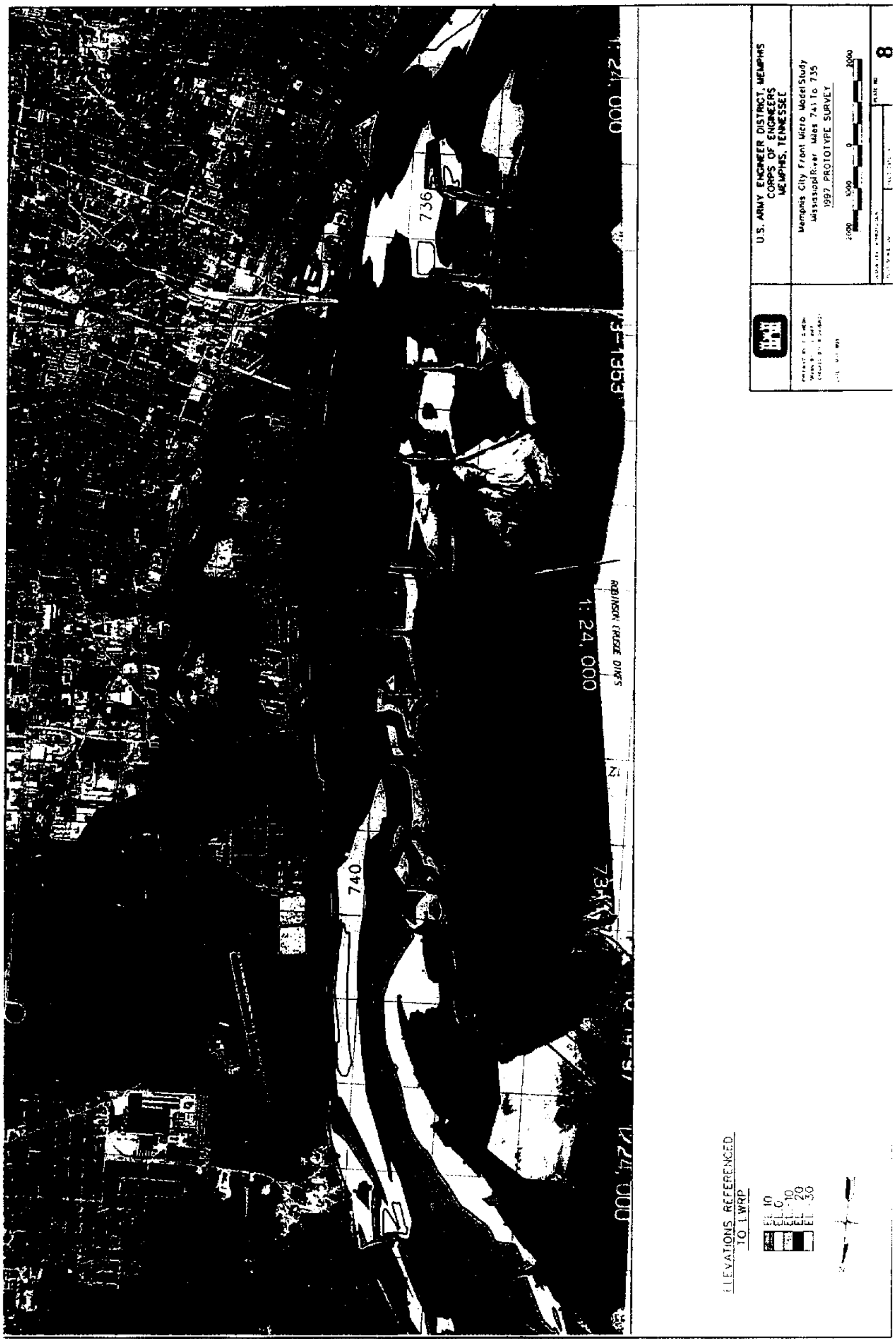

Figure C-5.1c Memphis Harbor Prototype Survey 1997

Figure C-5.1d Memphis Harbor Micromodel Base Test

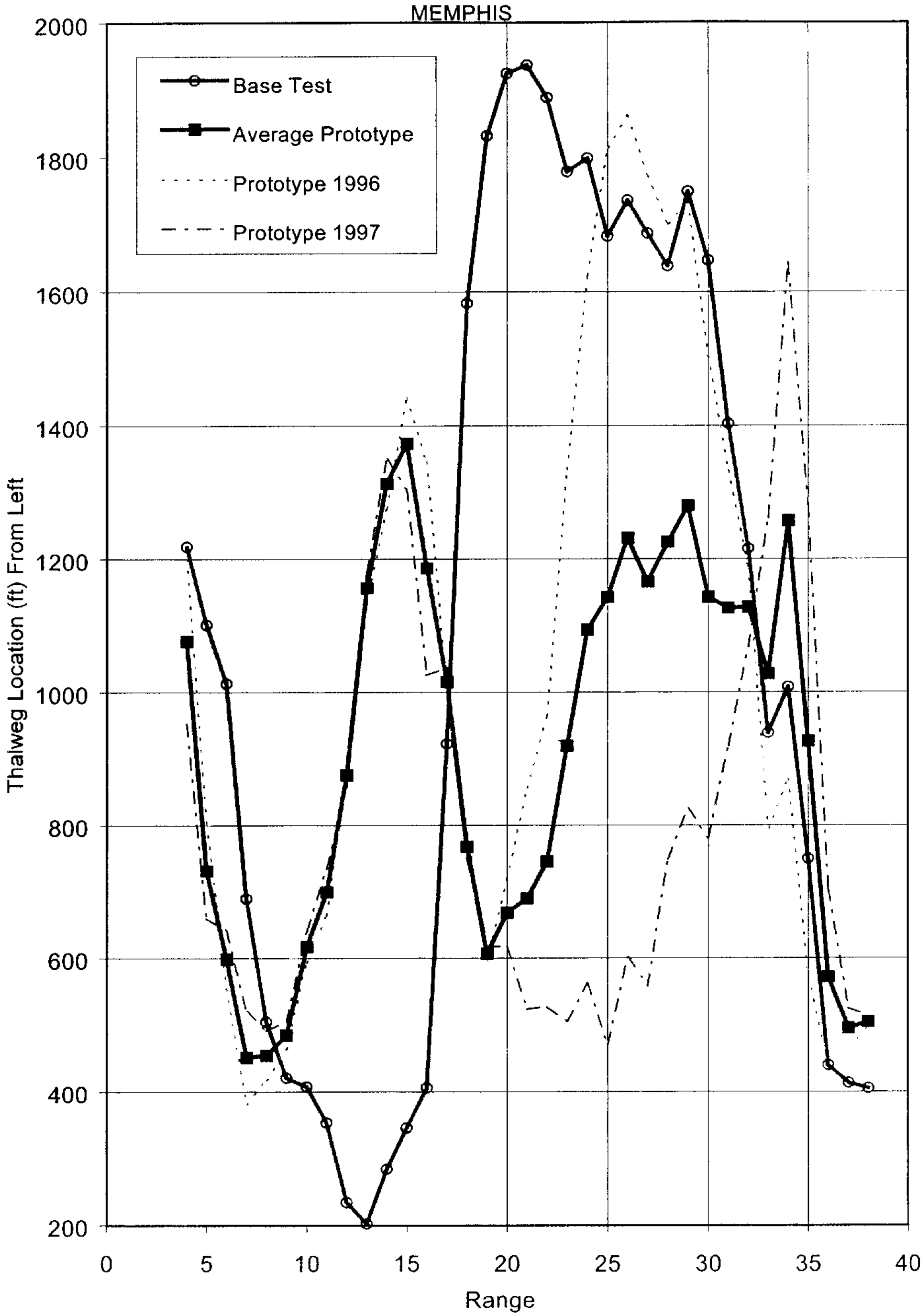

Figure C-5.2a Thalweg Distance From Left by Range, Memphis Harbor (Mississippi River)

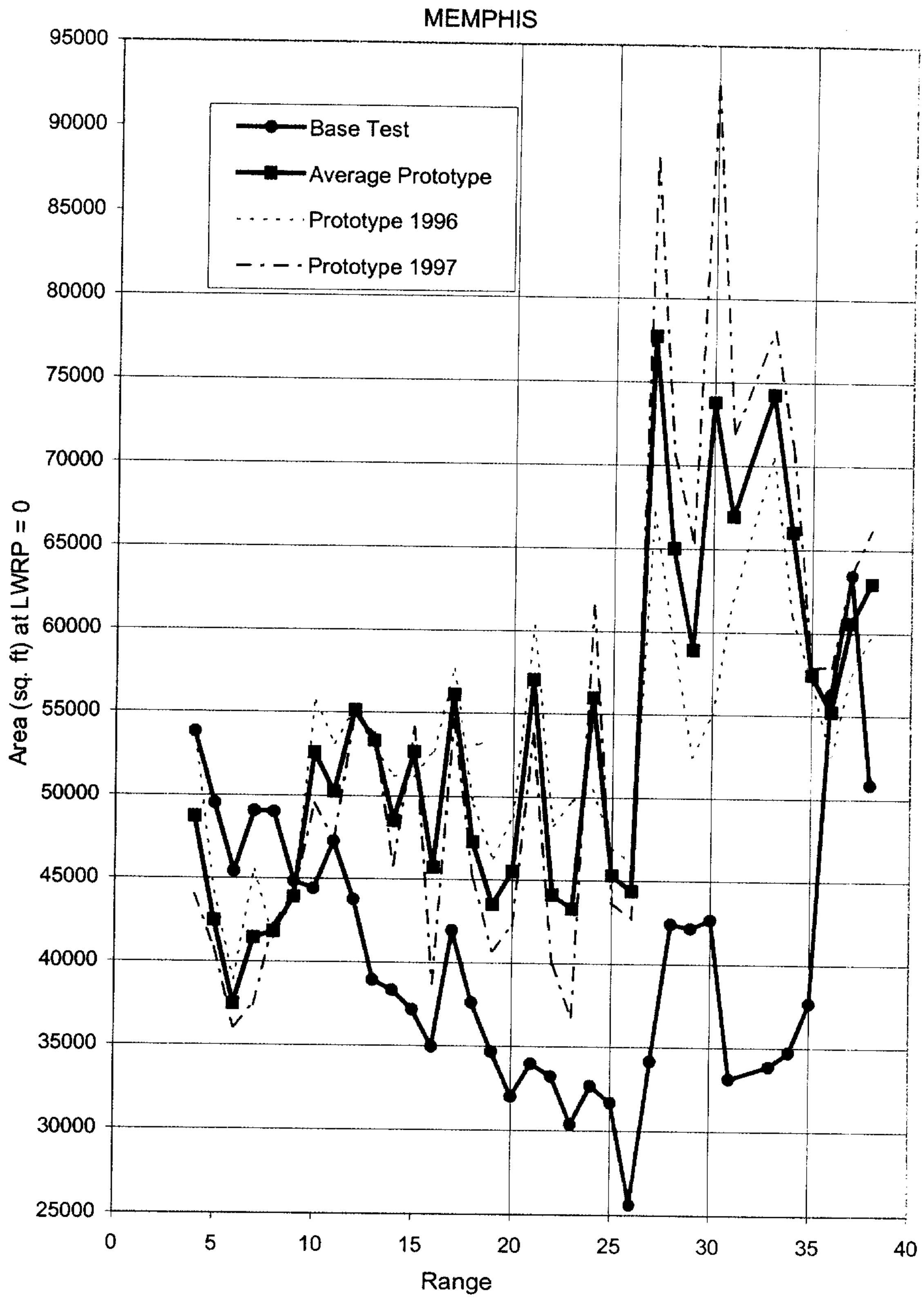

Figure C-5.2b Cross-Section Area by Range, Memphis Harbor (Mississippi River)

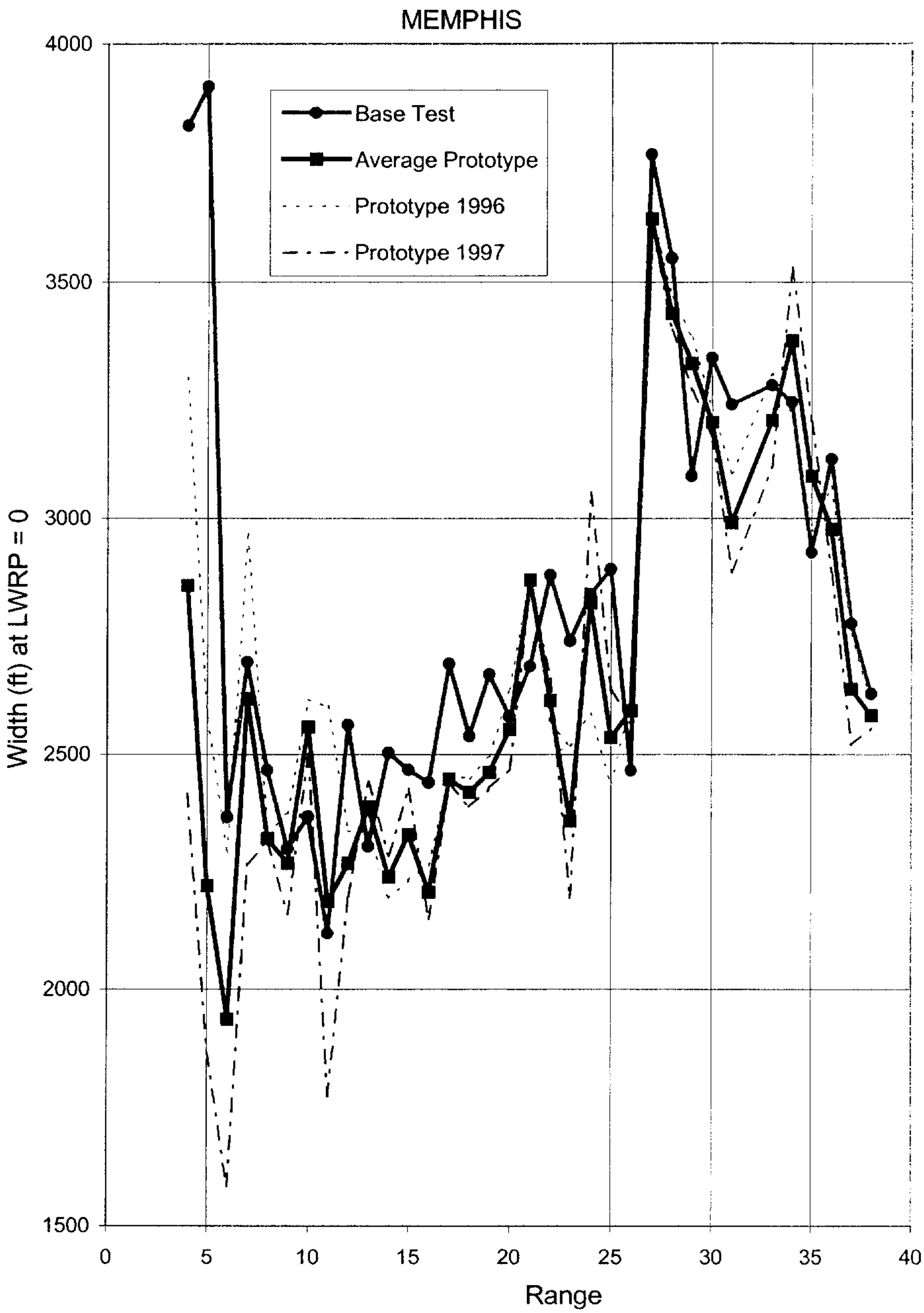

Figure C-5.2c Top Width by Range, Memphis Harbor (Mississippi River)

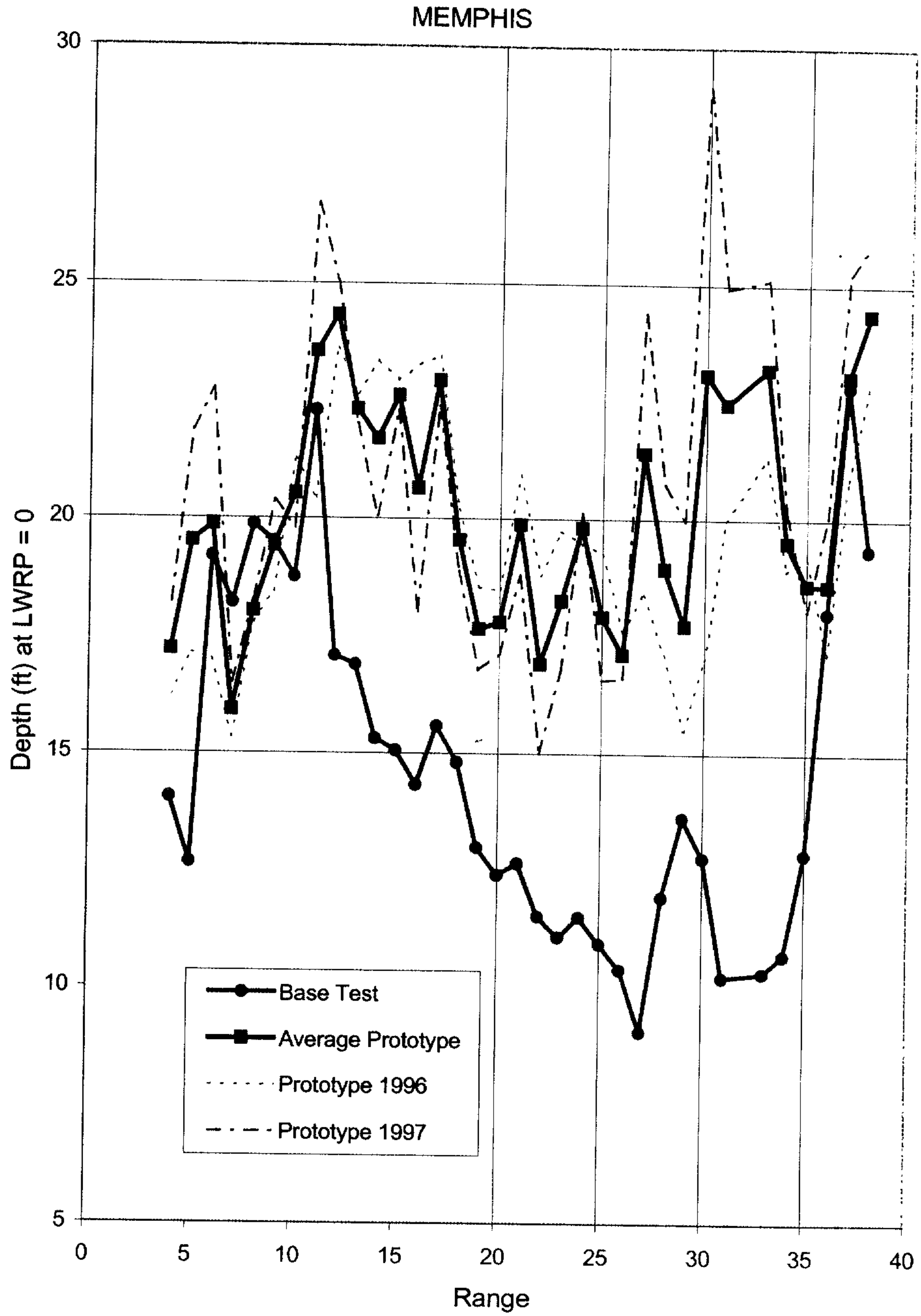

Figure C-5.2d Hydraulic Depth by Range, Memphis Harbor (Mississippi River)

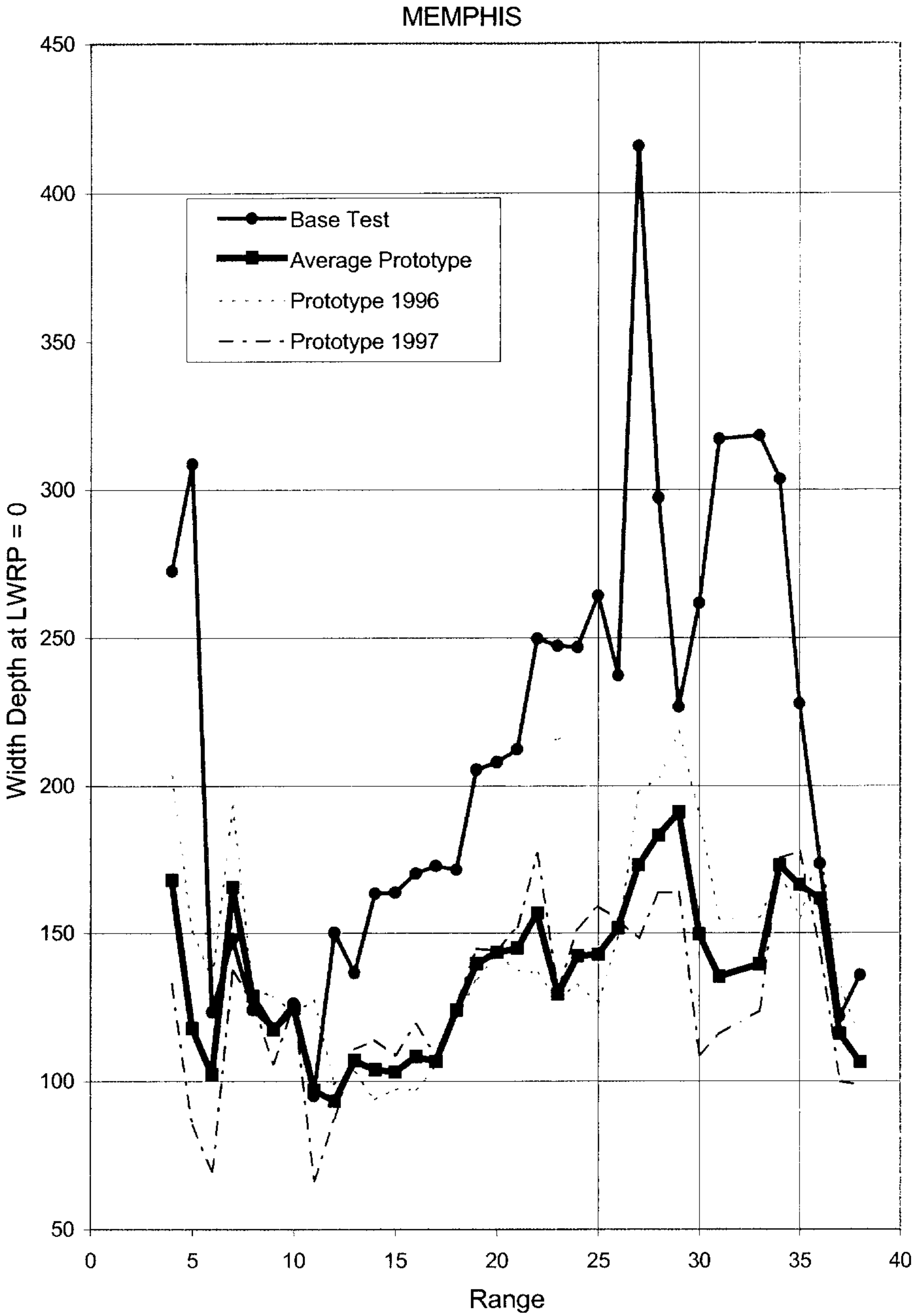

Figure C-5.2e Width/Depth Ratio by Range, Memphis Harbor (Mississippi River)

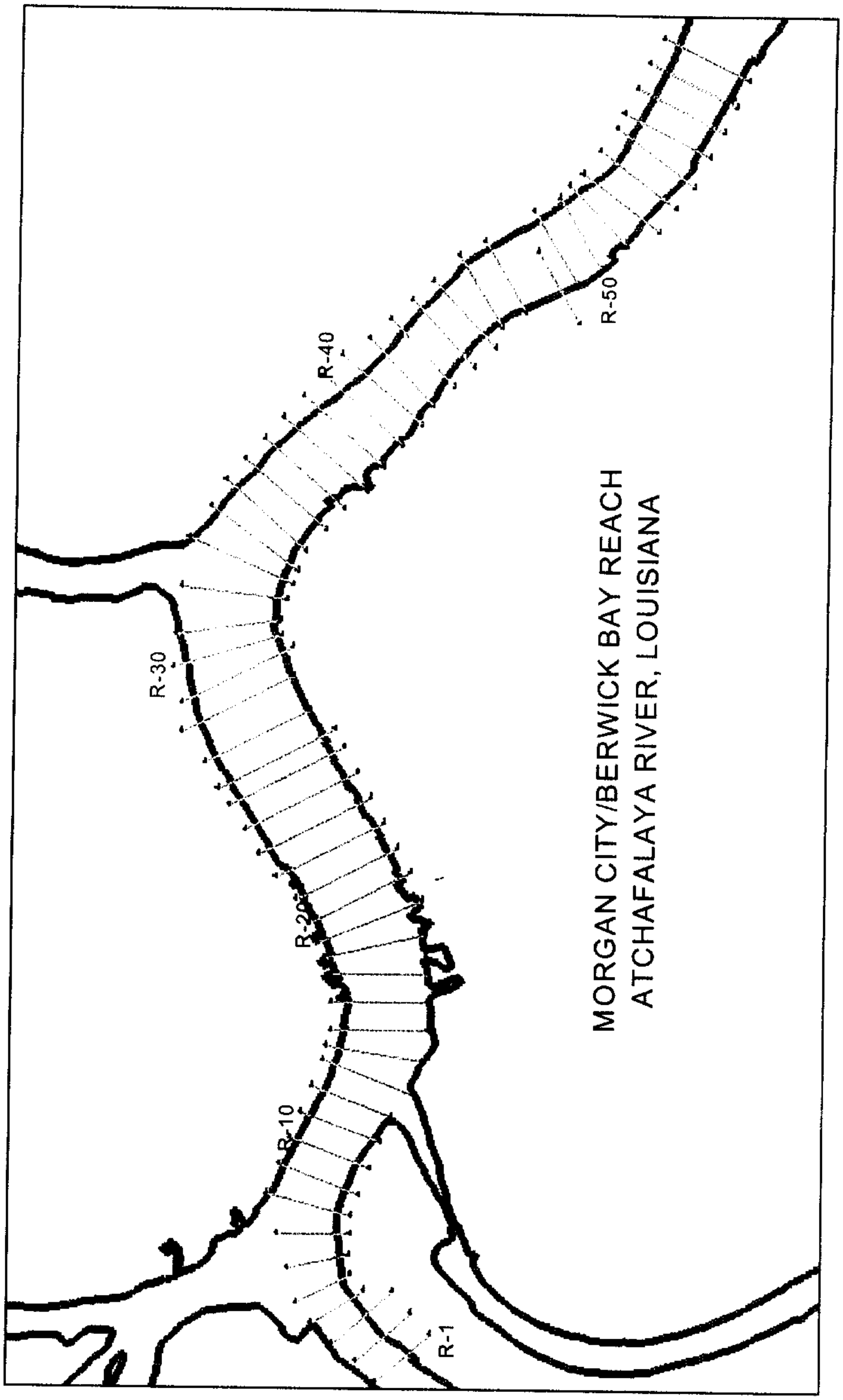

Figure C-6.1a Morgan City/Berwick Bay Micromodel Plan View

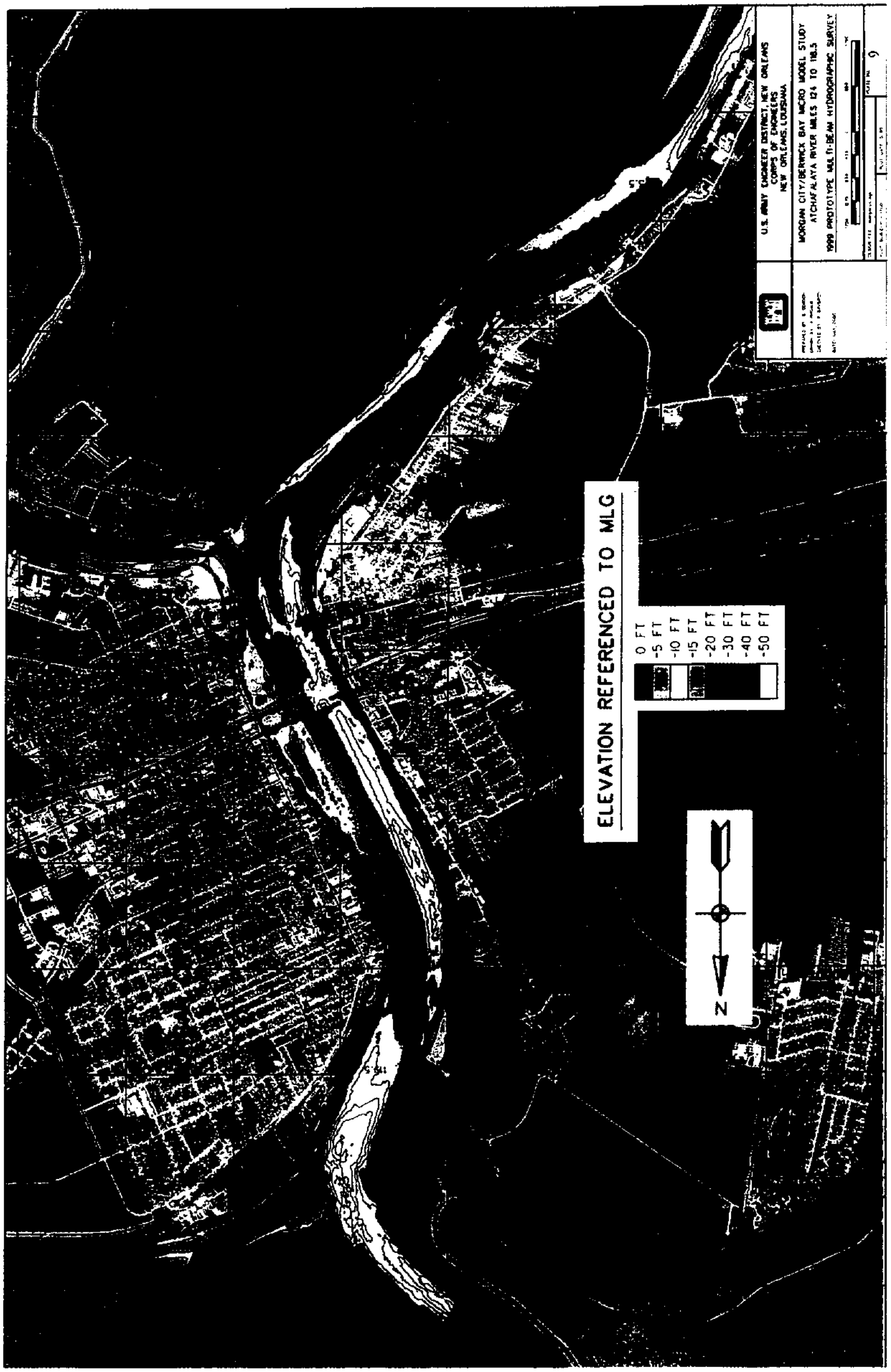

Figure C-6.1b Morgan City/Berwick Bay Prototype Survey 1999

Figure C-6.1c Morgan City/Berwick Bay Micromodel Base Test

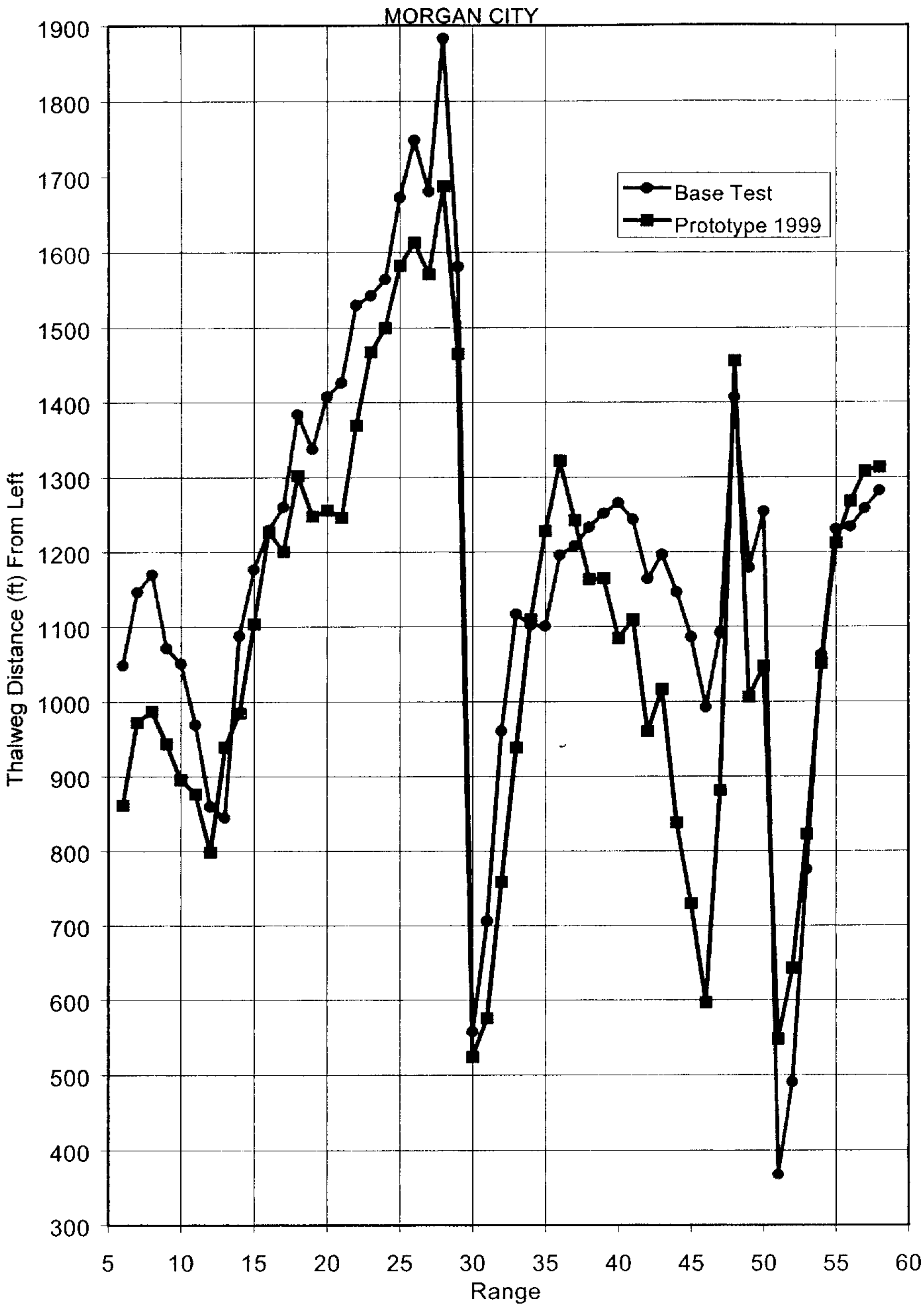

Figure C-6.2a Thalweg Position From Left by Range, Morgan City (Atchafalaya River)

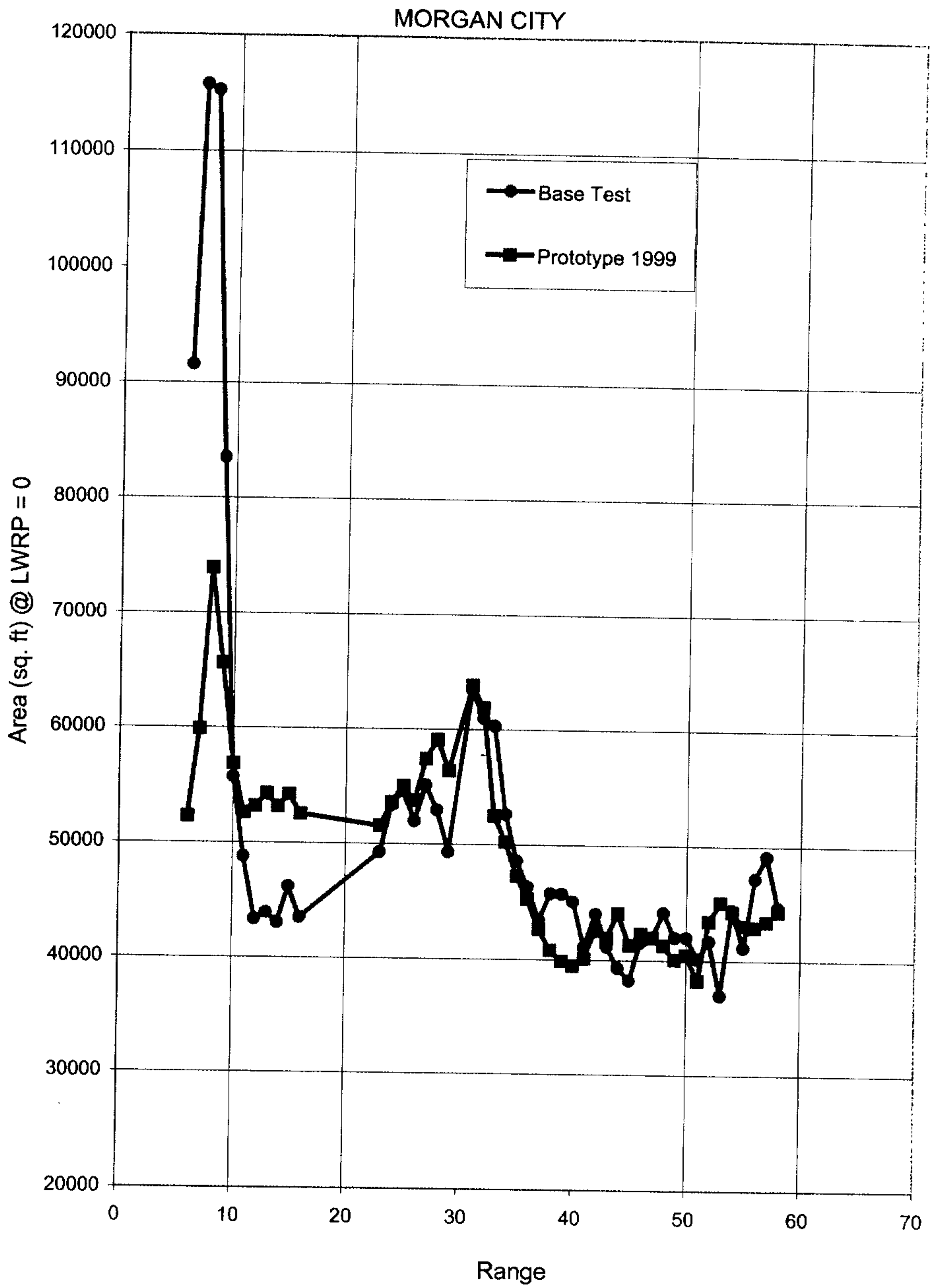

Figure C-6.2b Cross-Section Area, Morgan City (Atchafalaya River)

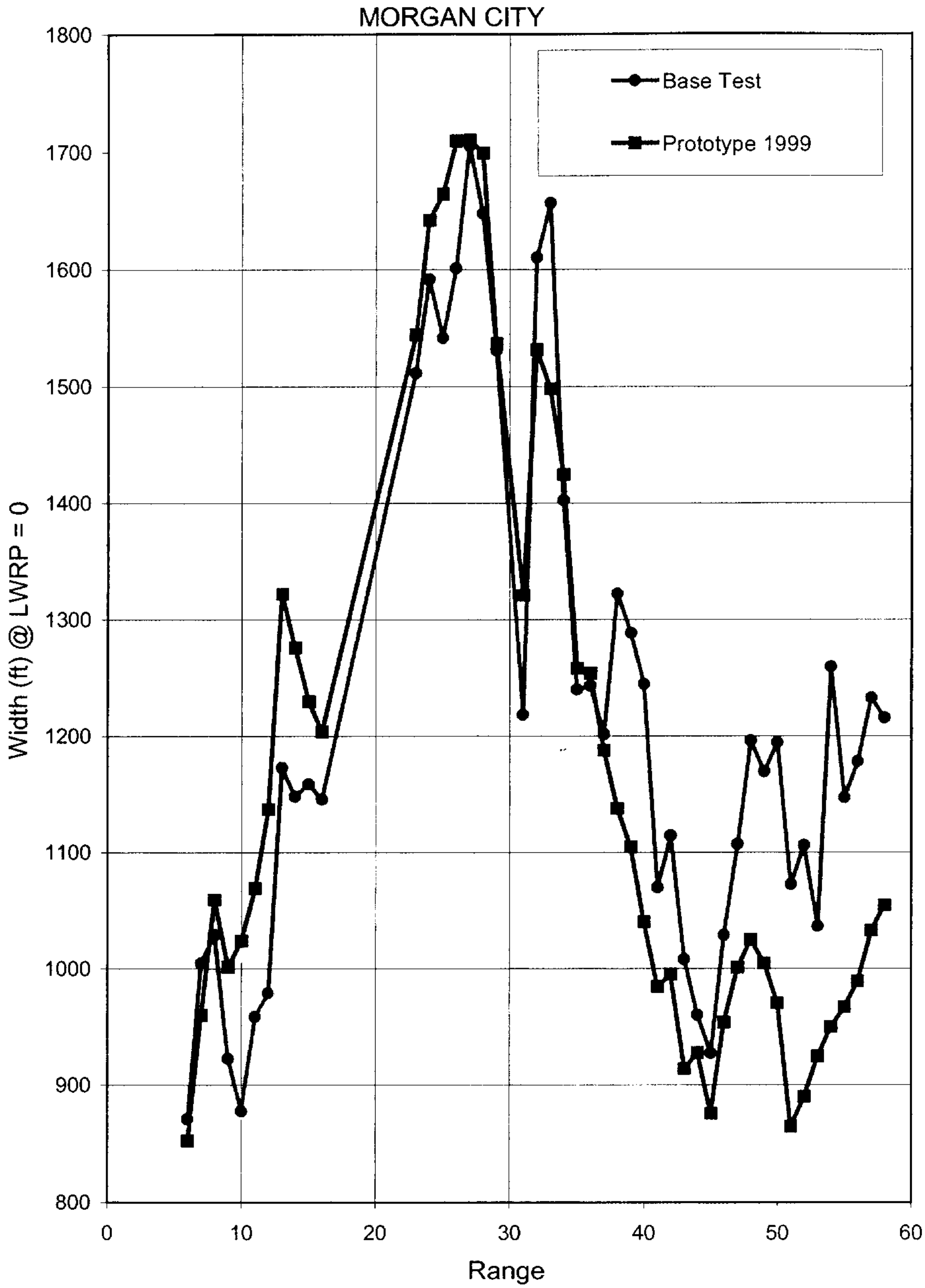

Figure C-6.2cTop Width by Section, Morgan City (Atchafalaya River)

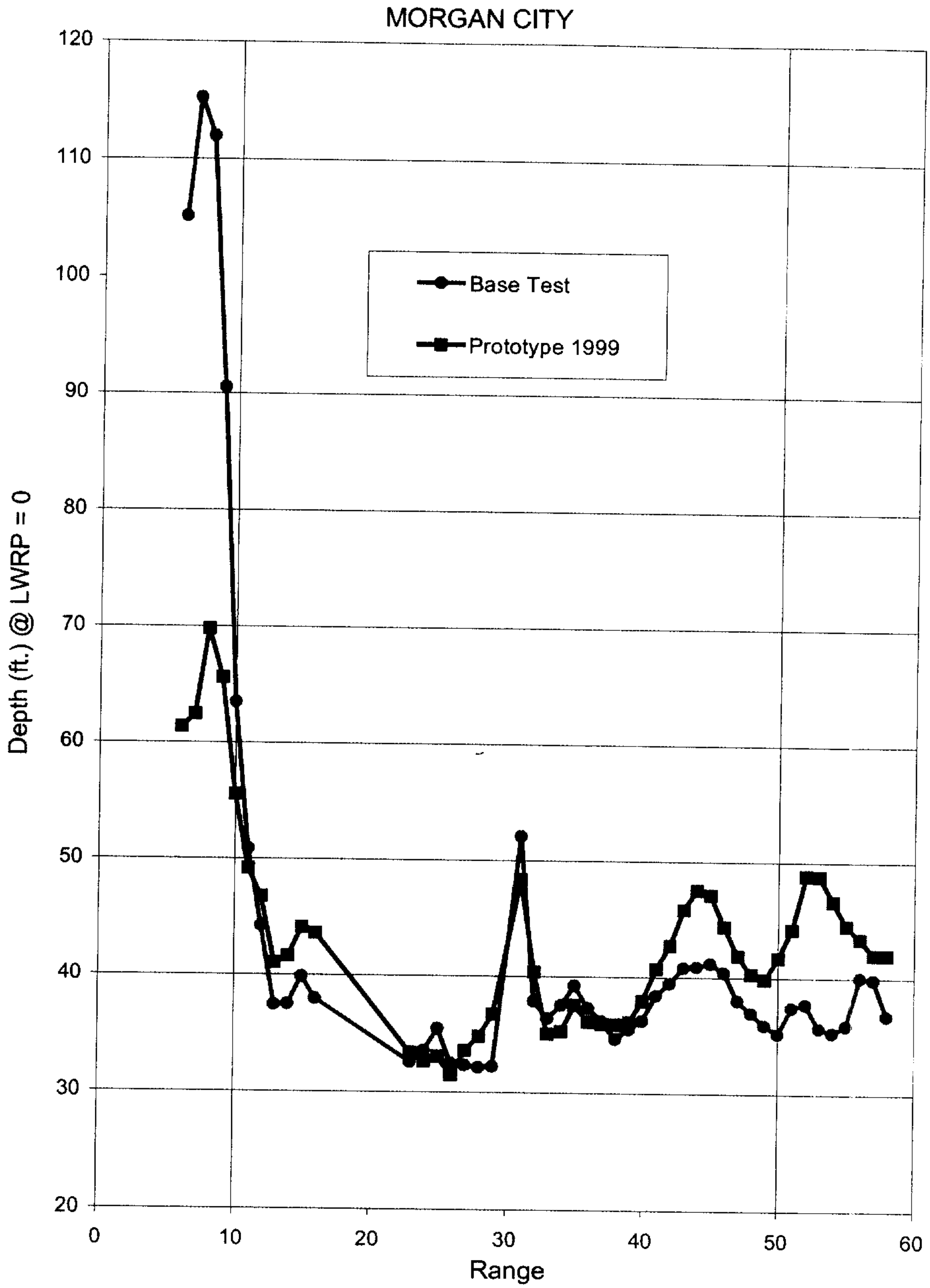

Figure C-6.2d Hydraulic Depth by Section, Morgan City (Atchafalaya River)

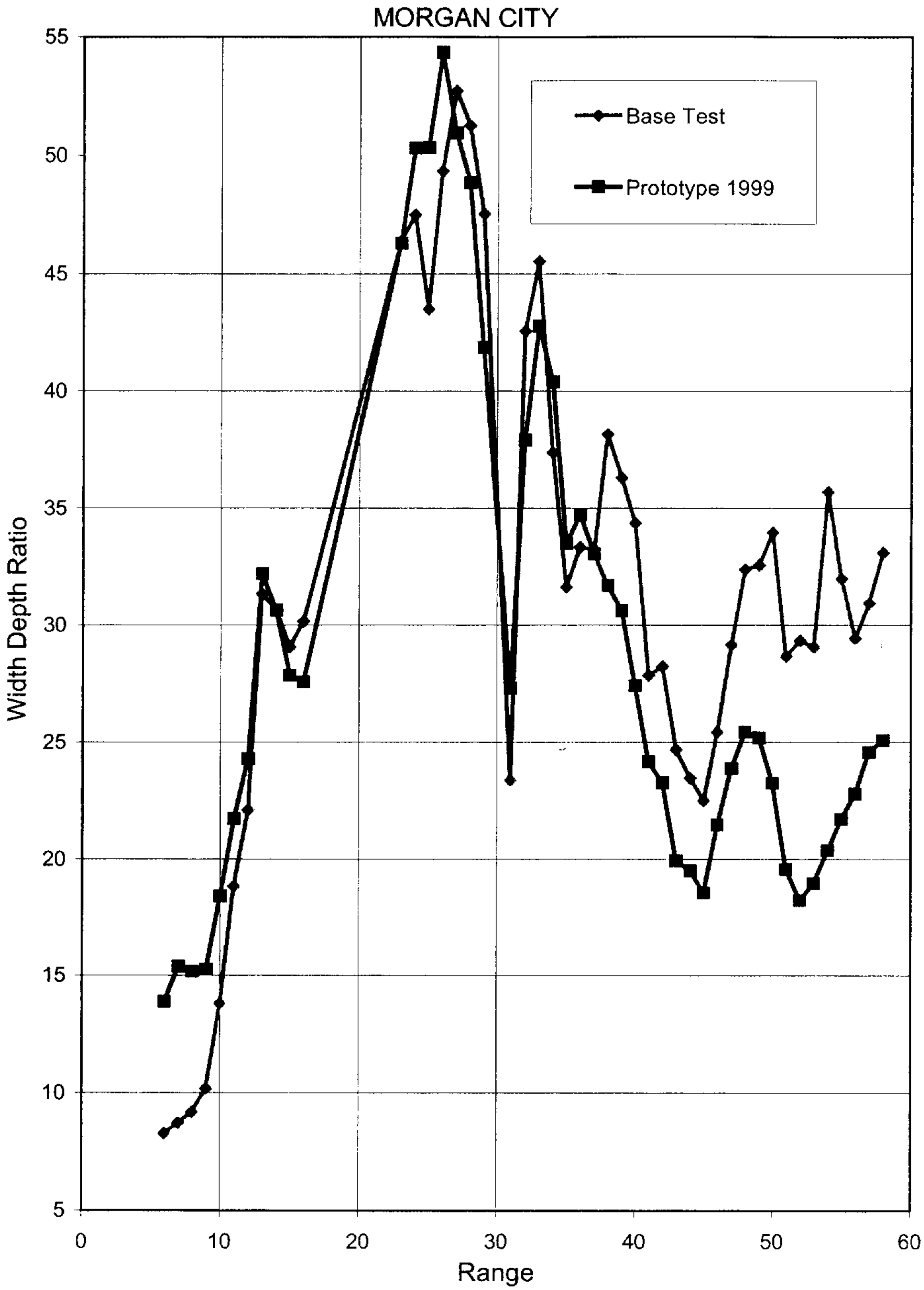

Figure C-6.2e Width/Depth Ratio by Range, Morgan City (Atchafalaya River)

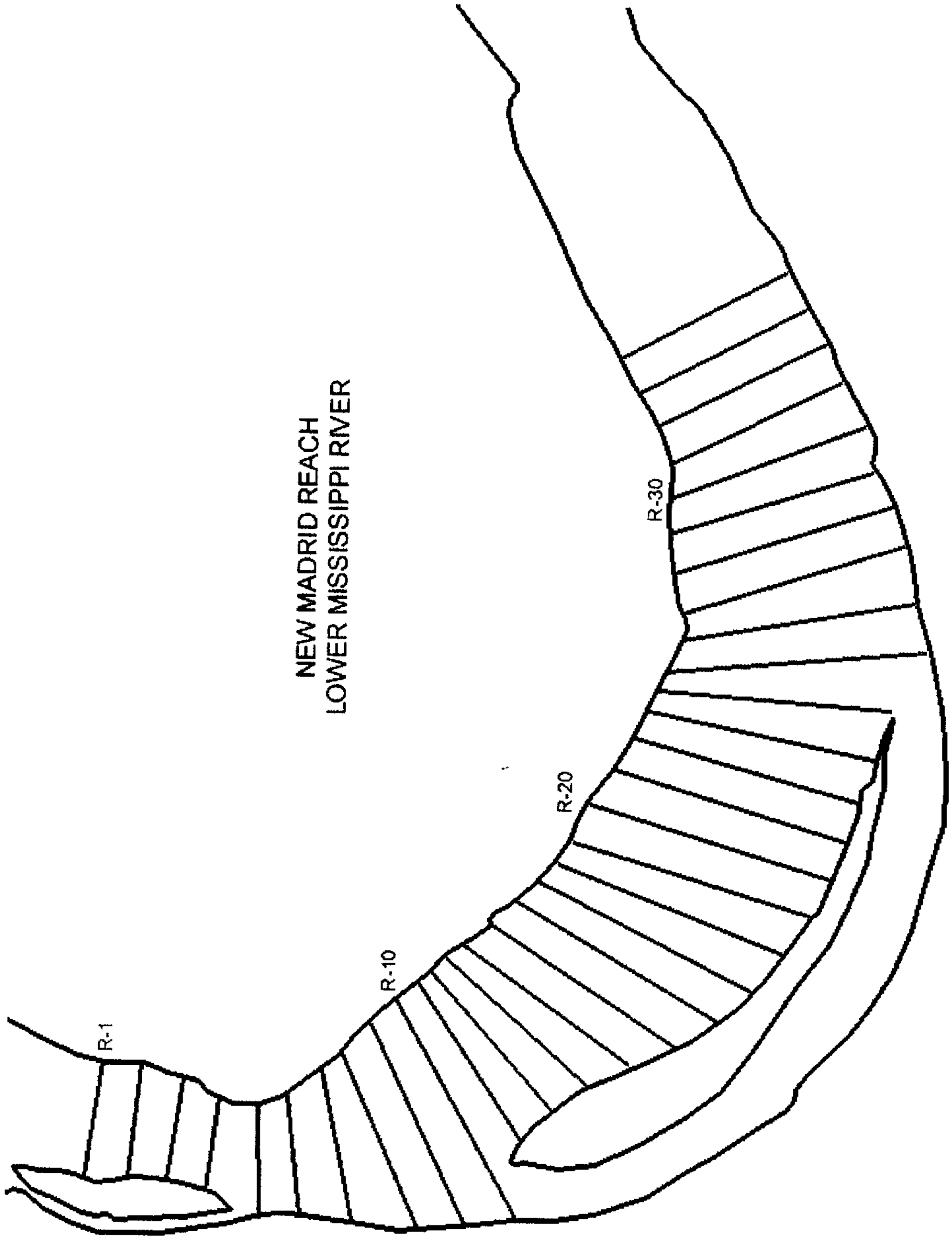

Figure C-7.1a New Madrid Micromodel Plan View

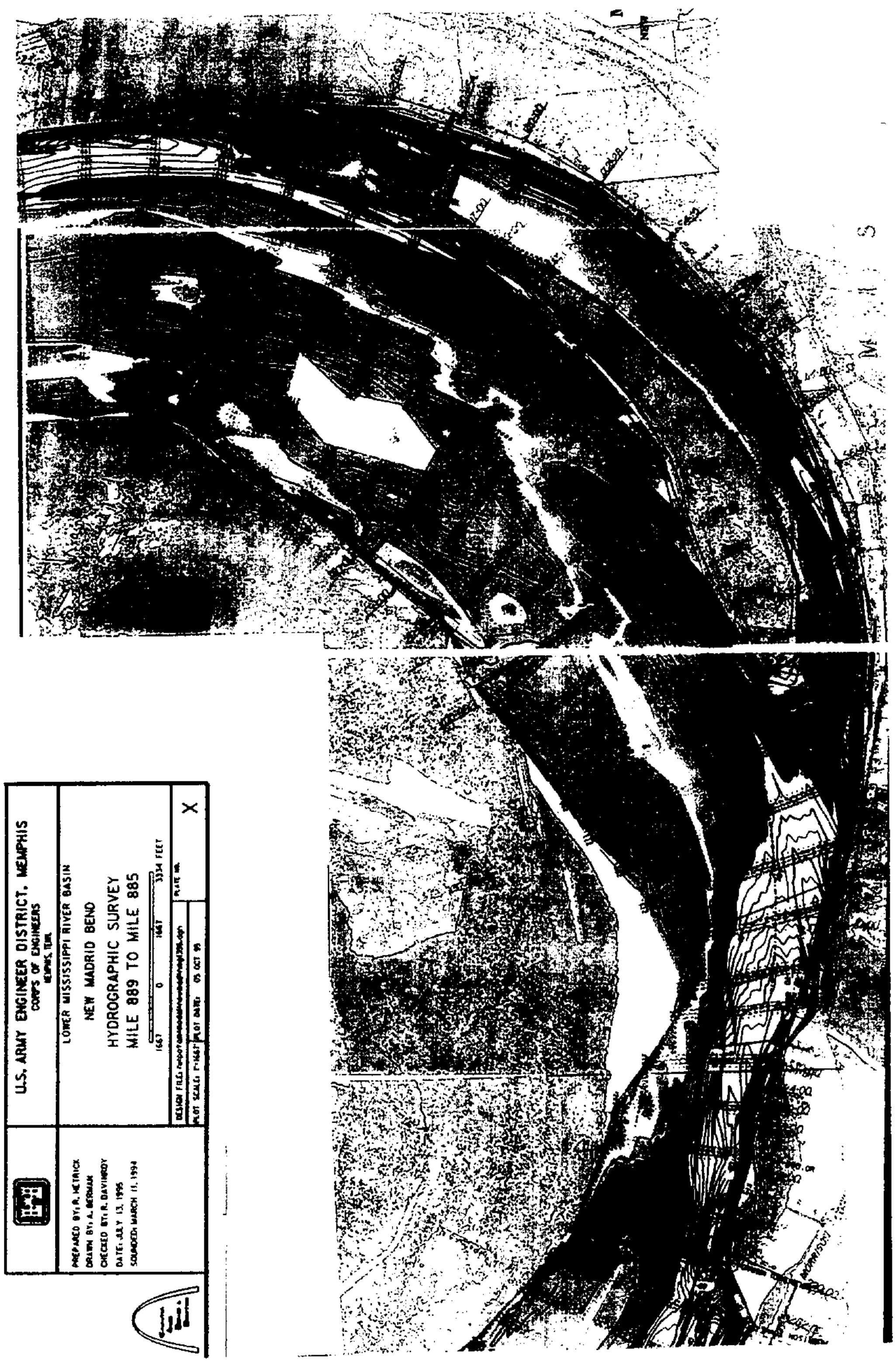

Figure C-7.1b New Madrid Prototype Survey 1994

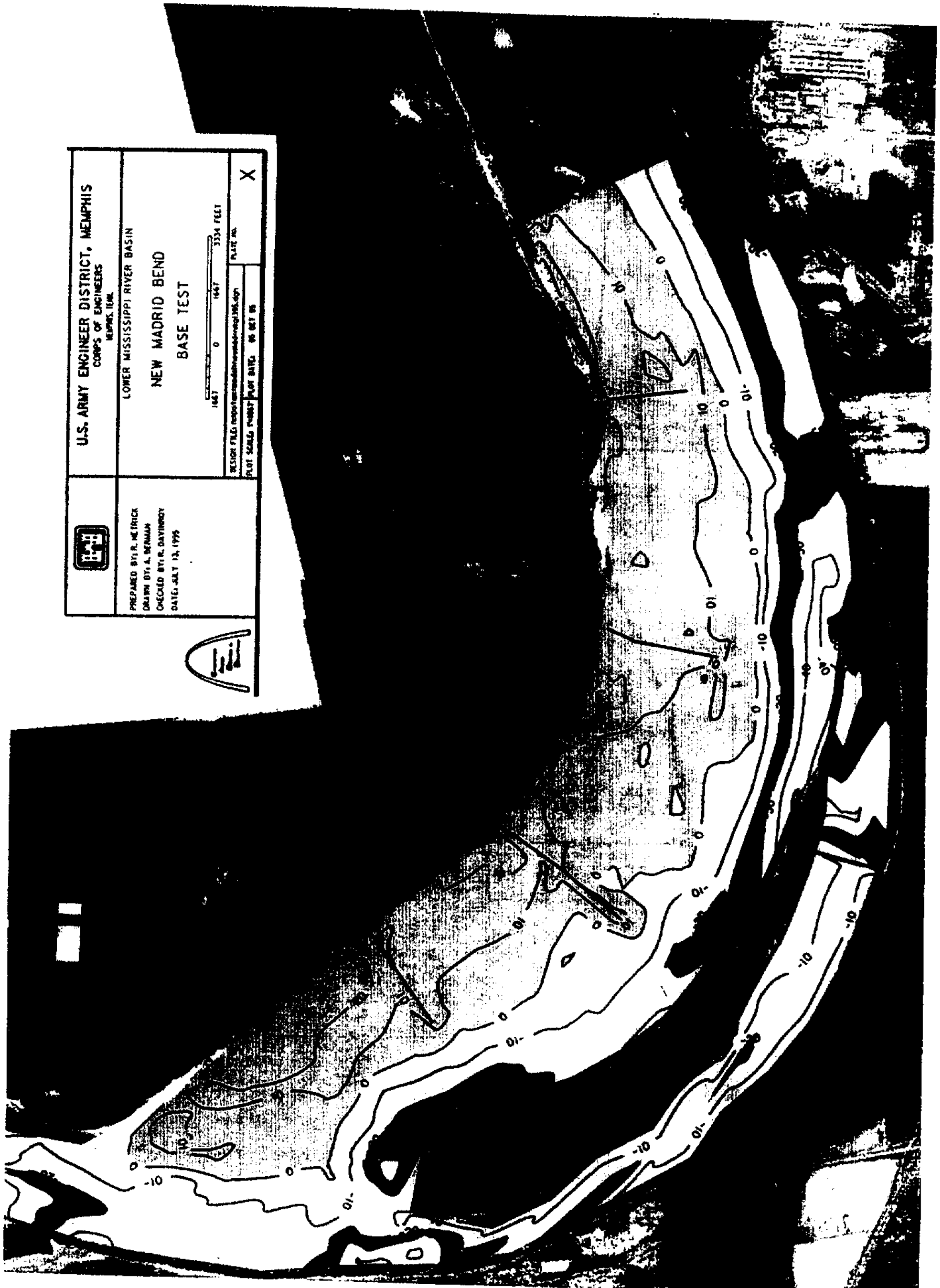

Figure C-7.1c New Madrid Micromodel Base Test

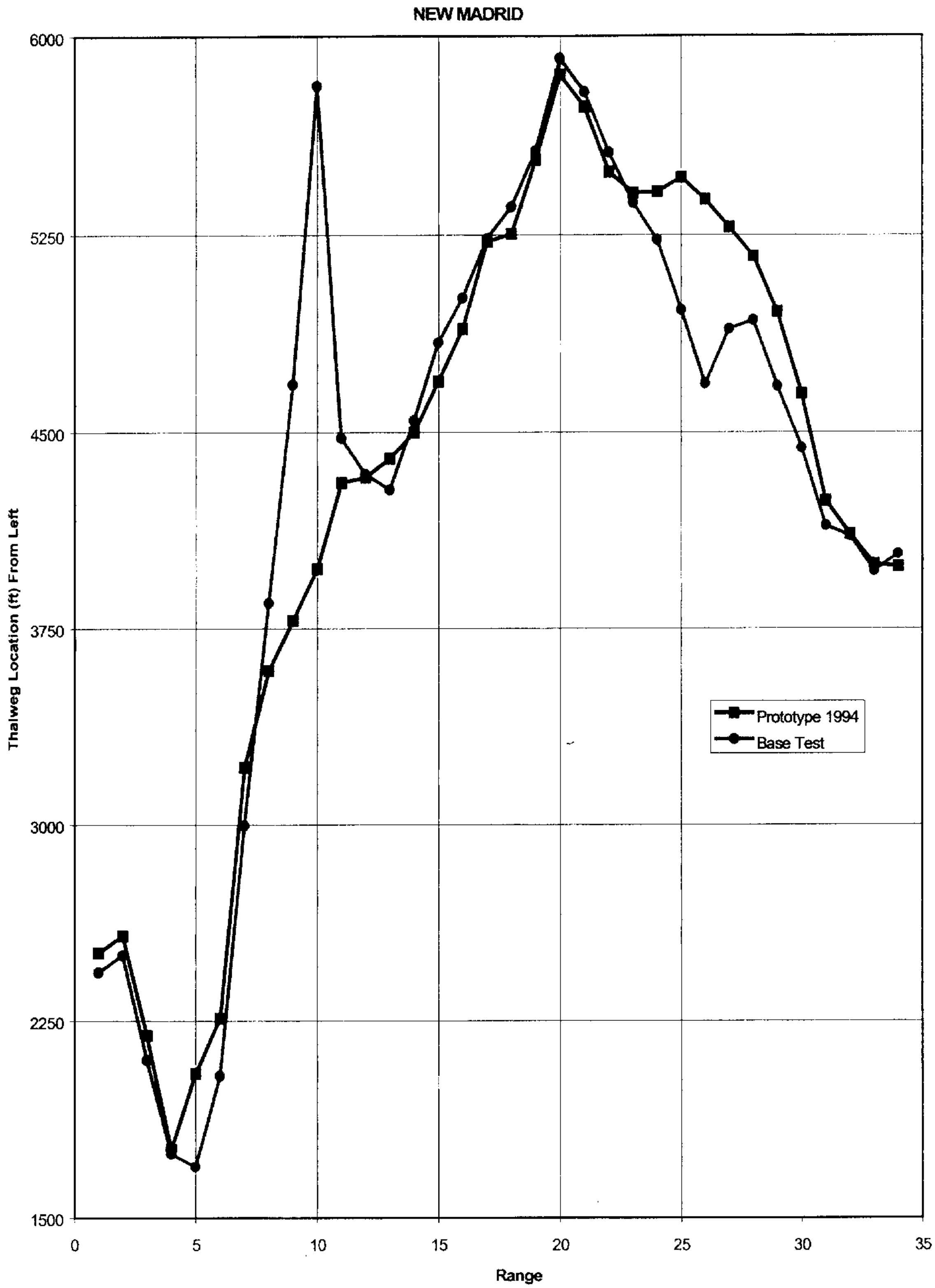

Figure C-7.2a Thalweg Position From Left by Range, New Madrid Reach (Mississippi River)

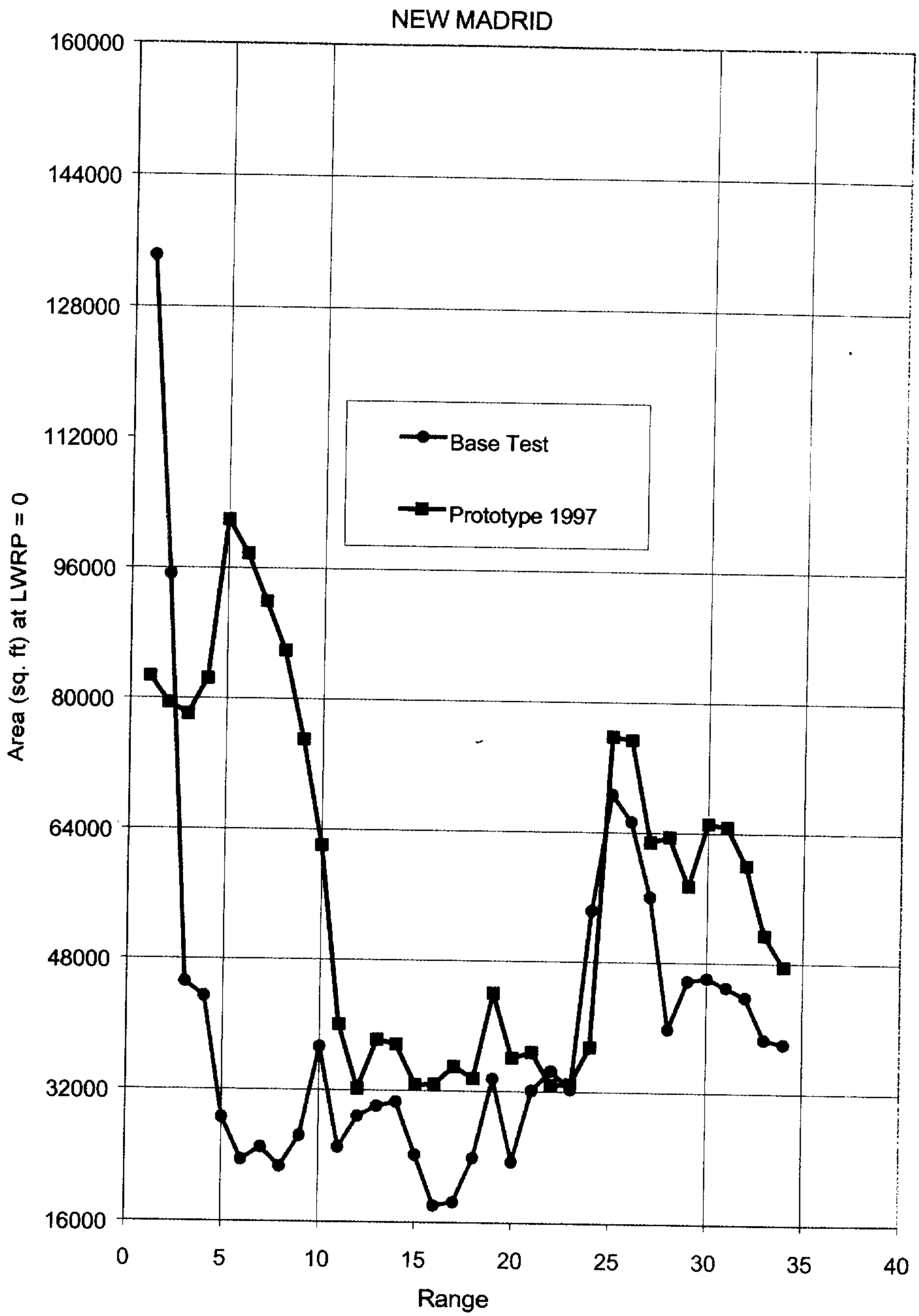

Figure C-7.2b Cross-Section Area by Range, New Madrid Reach (Mississippi River)

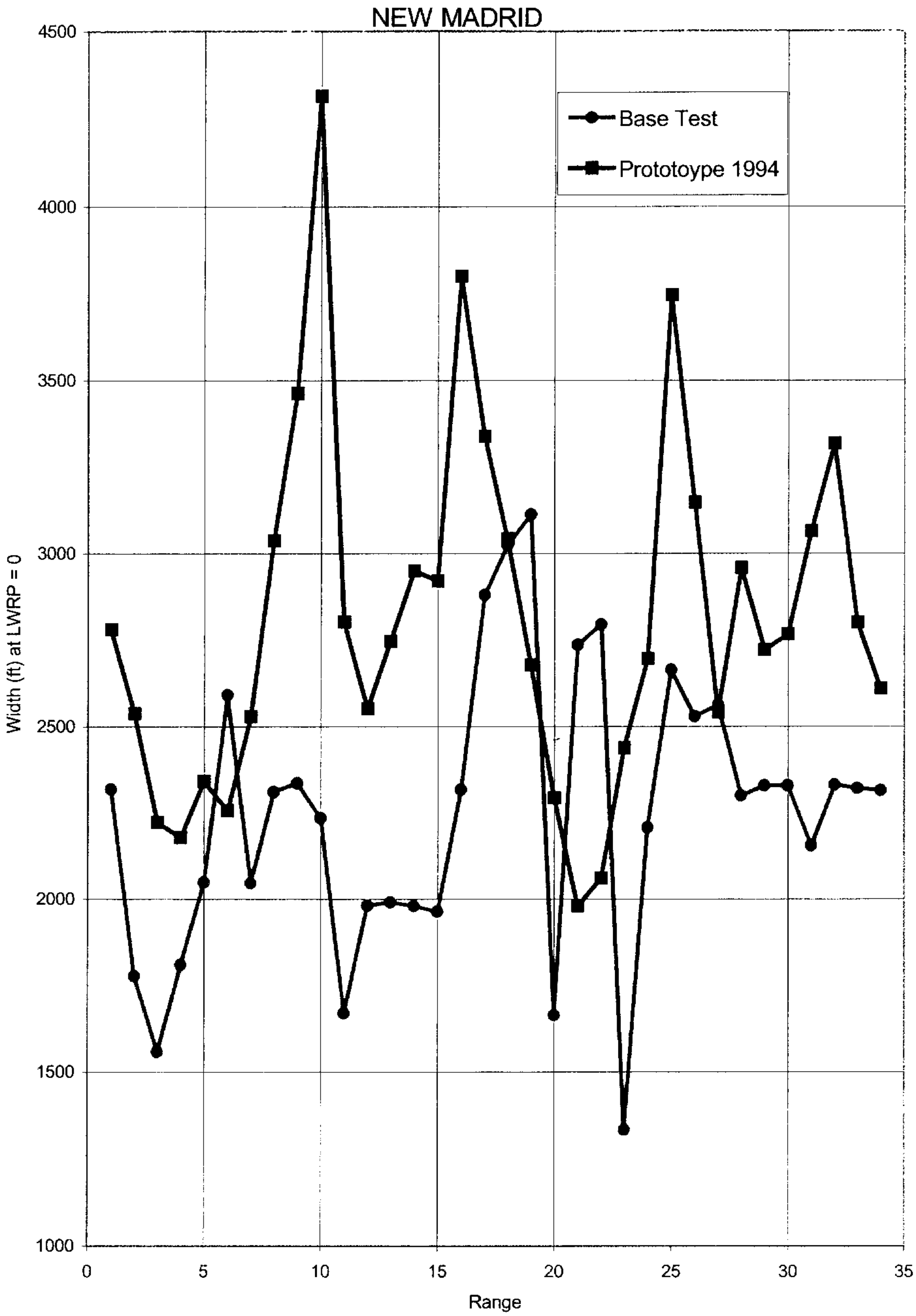

Figure C-7.2c Top Width by Range, New Madrid Reach (Mississippi River)

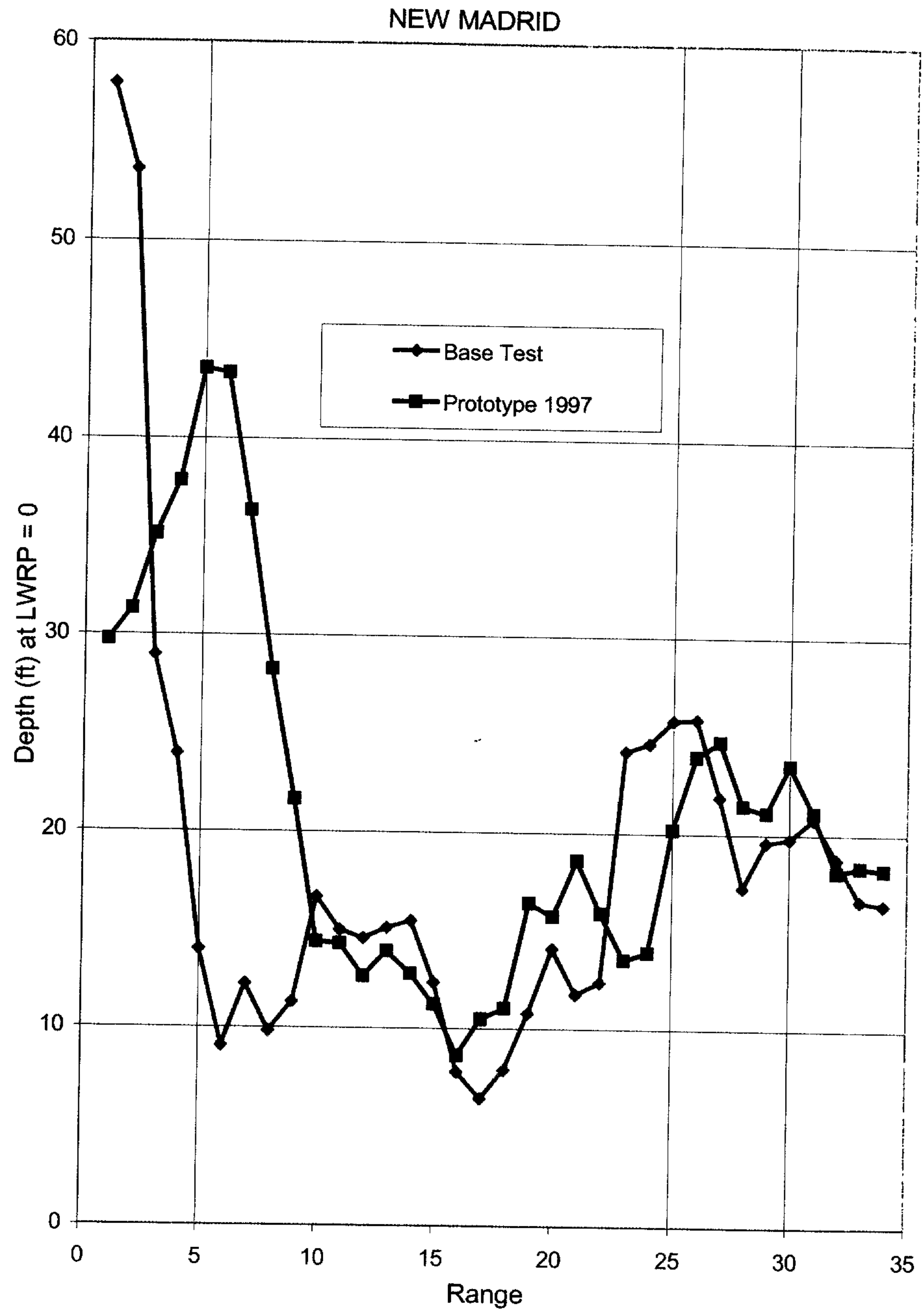

Figure C-7.2d Hydraulic Depth by Range, New Madrid Reach (Mississippi River)

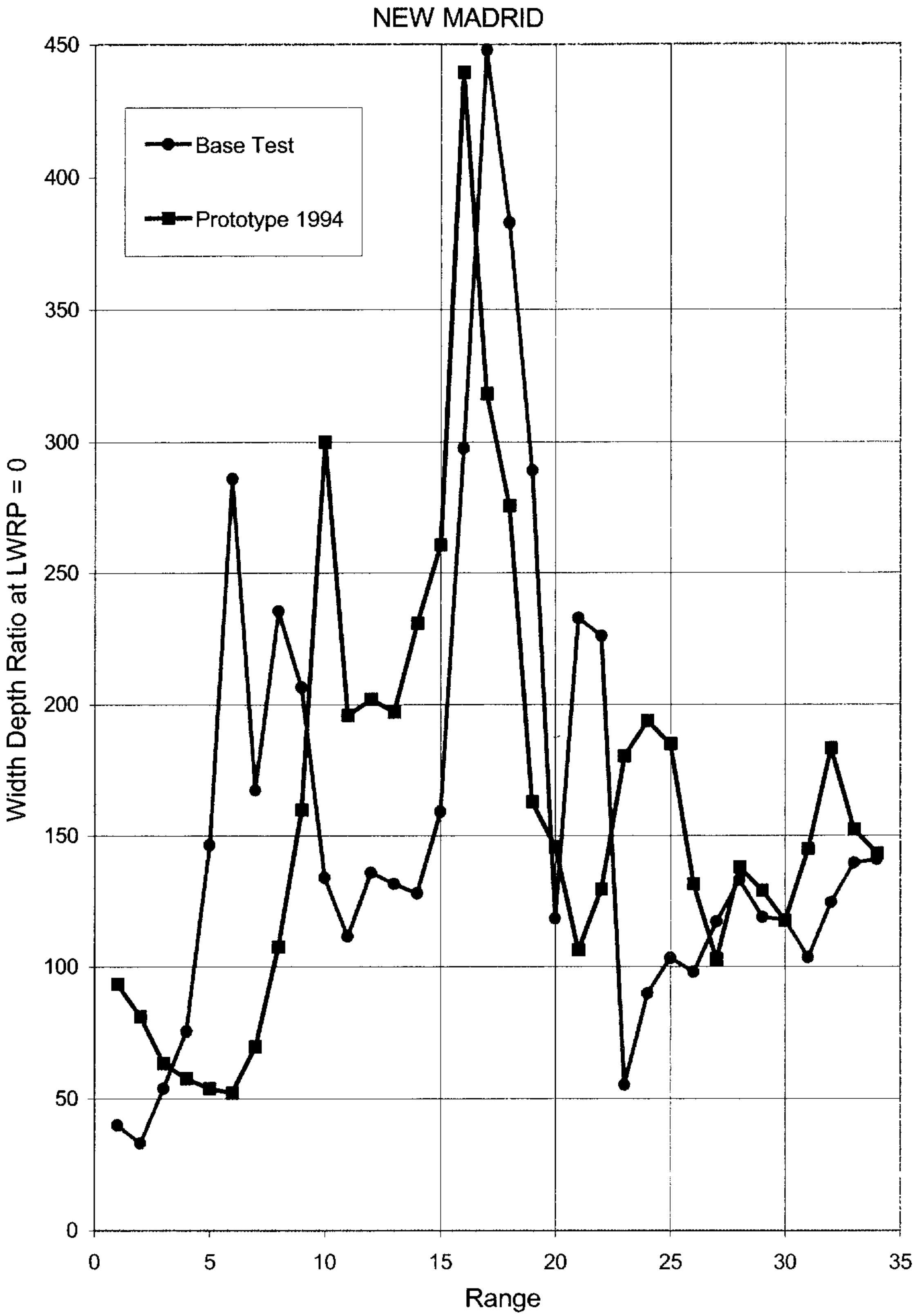

Figure C-7.2e Width/Depth Ratio by Range, New Madrid Reach (Mississippi River)

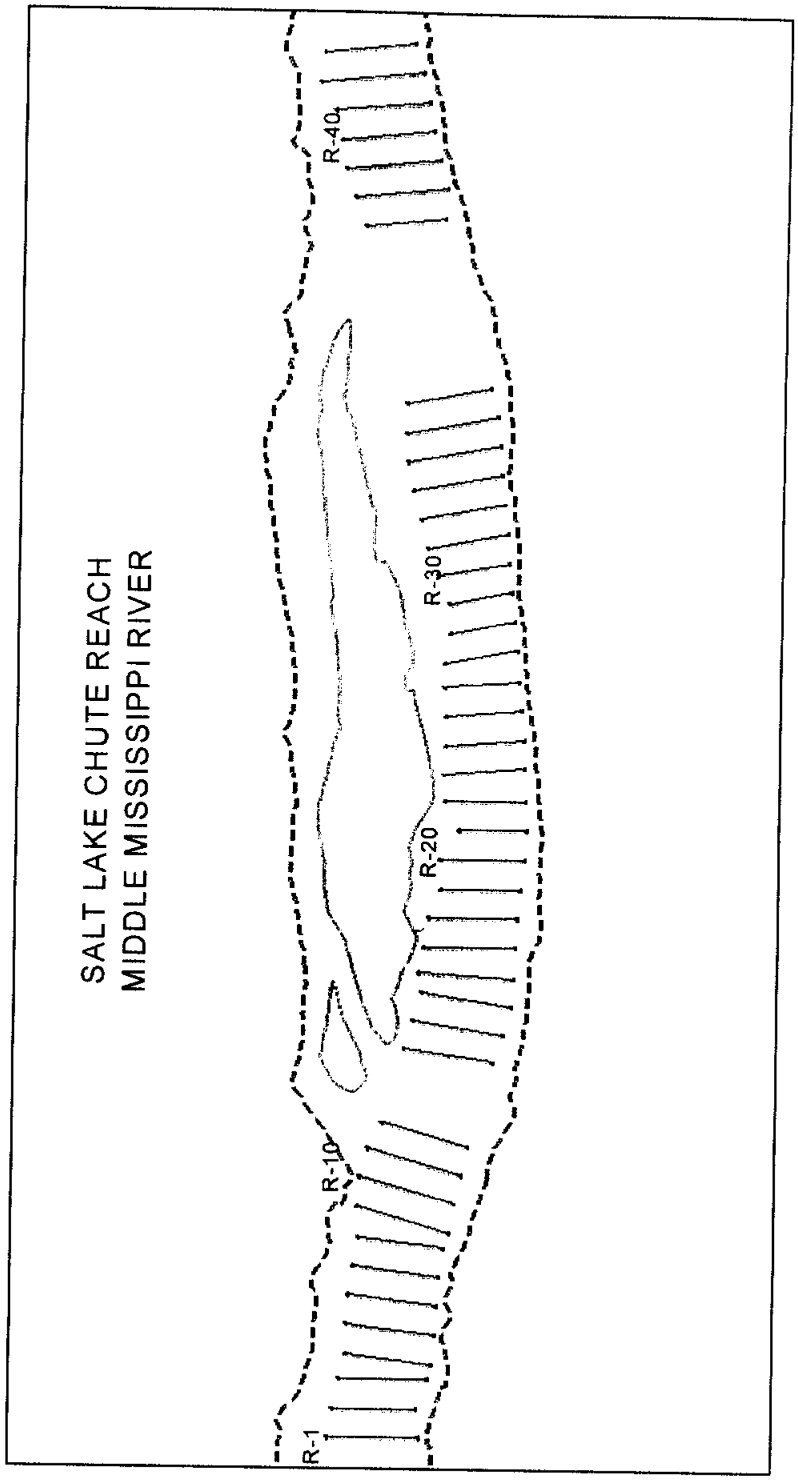

Figure C-8.1a Salt Lake Chute Micromodel Plan View

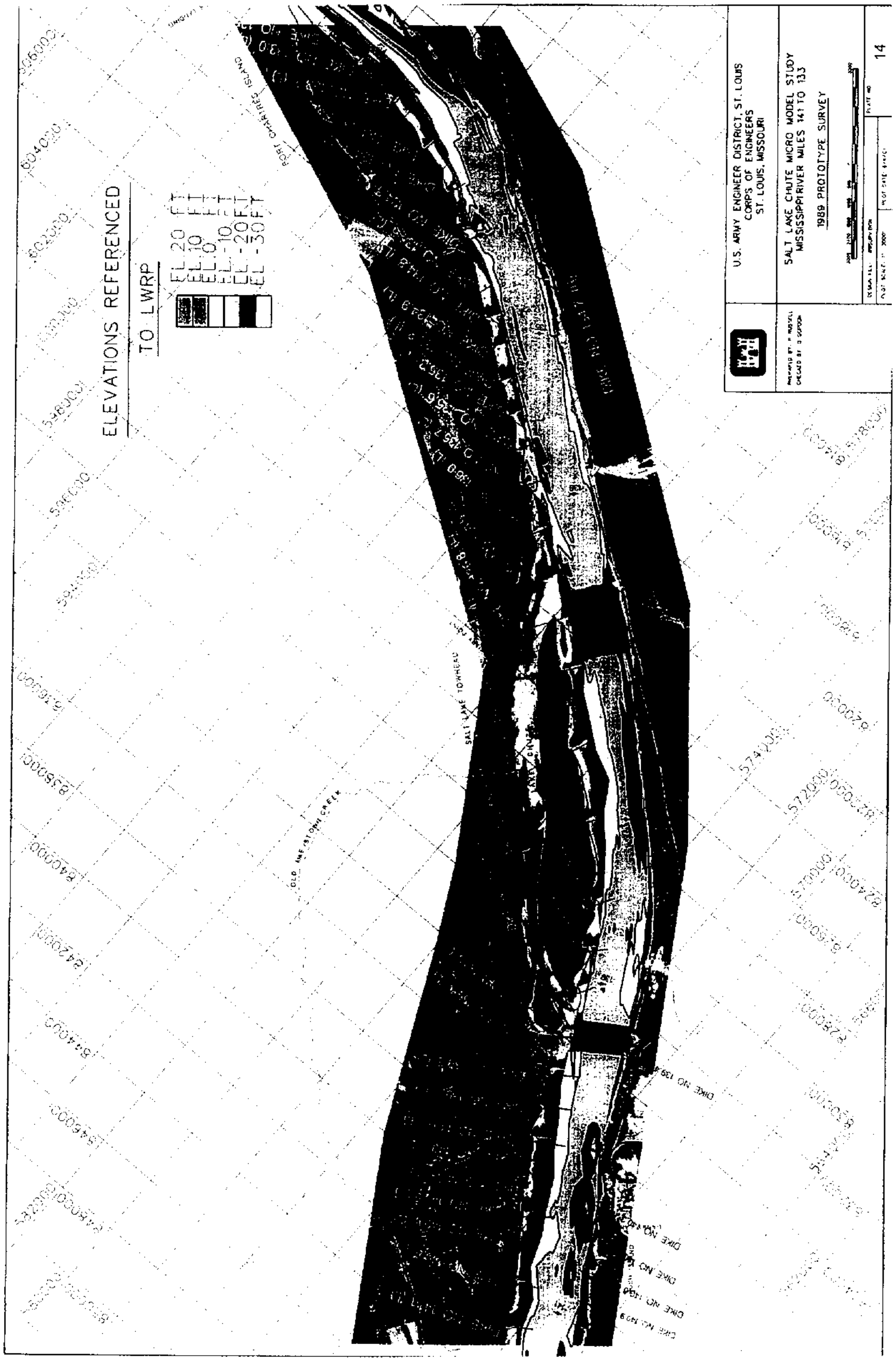

Figure C-8.1b Salt Lake Chute Prototype Survey 1989

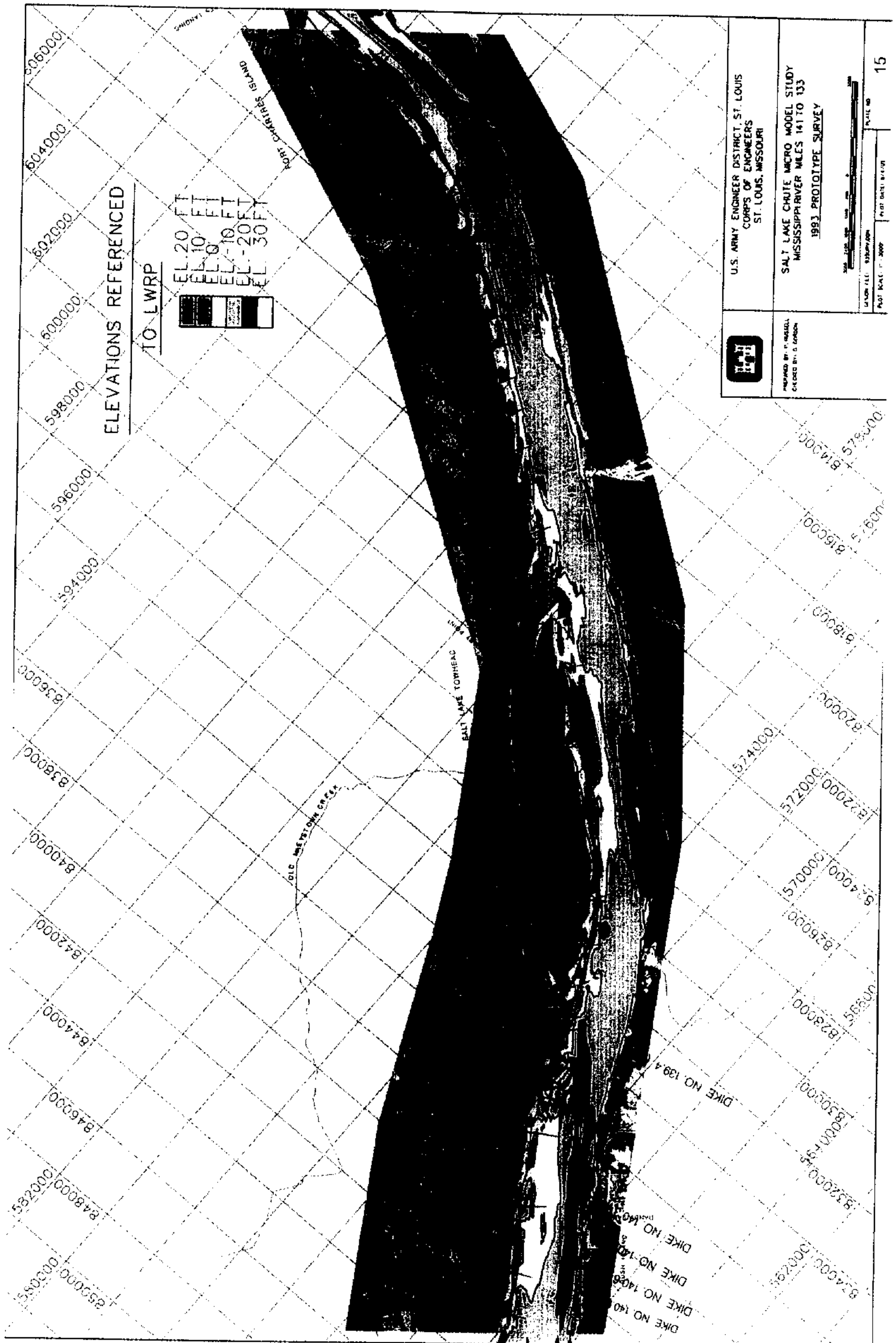

Figure C-8.1c Salt Lake Chute Prototype Survey 1993

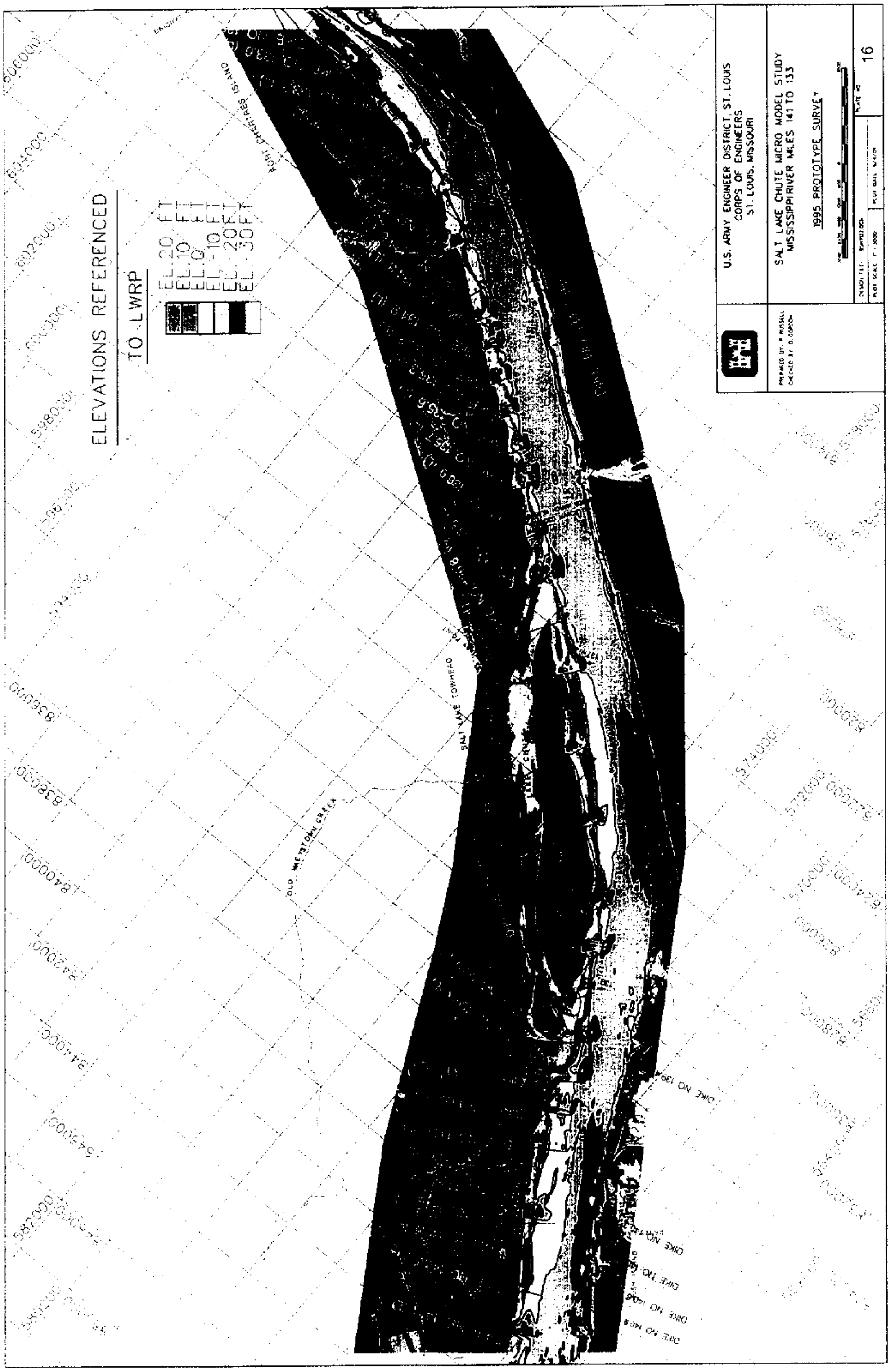

Figure C-8.1d Salt Lake Chute Prototype Survey 1995

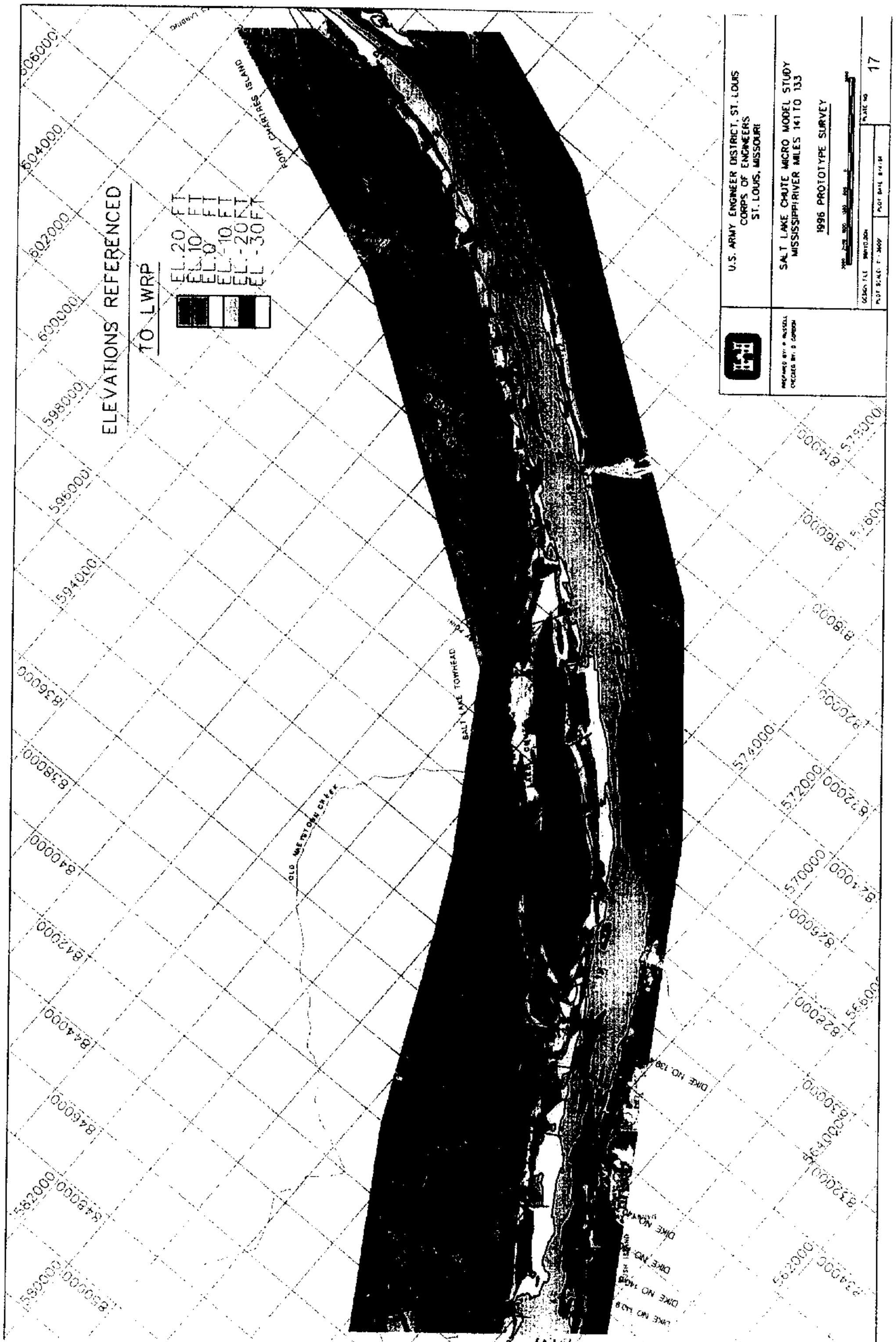

Figure C-8.1e Salt Lake Chute Prototype Survey 1996

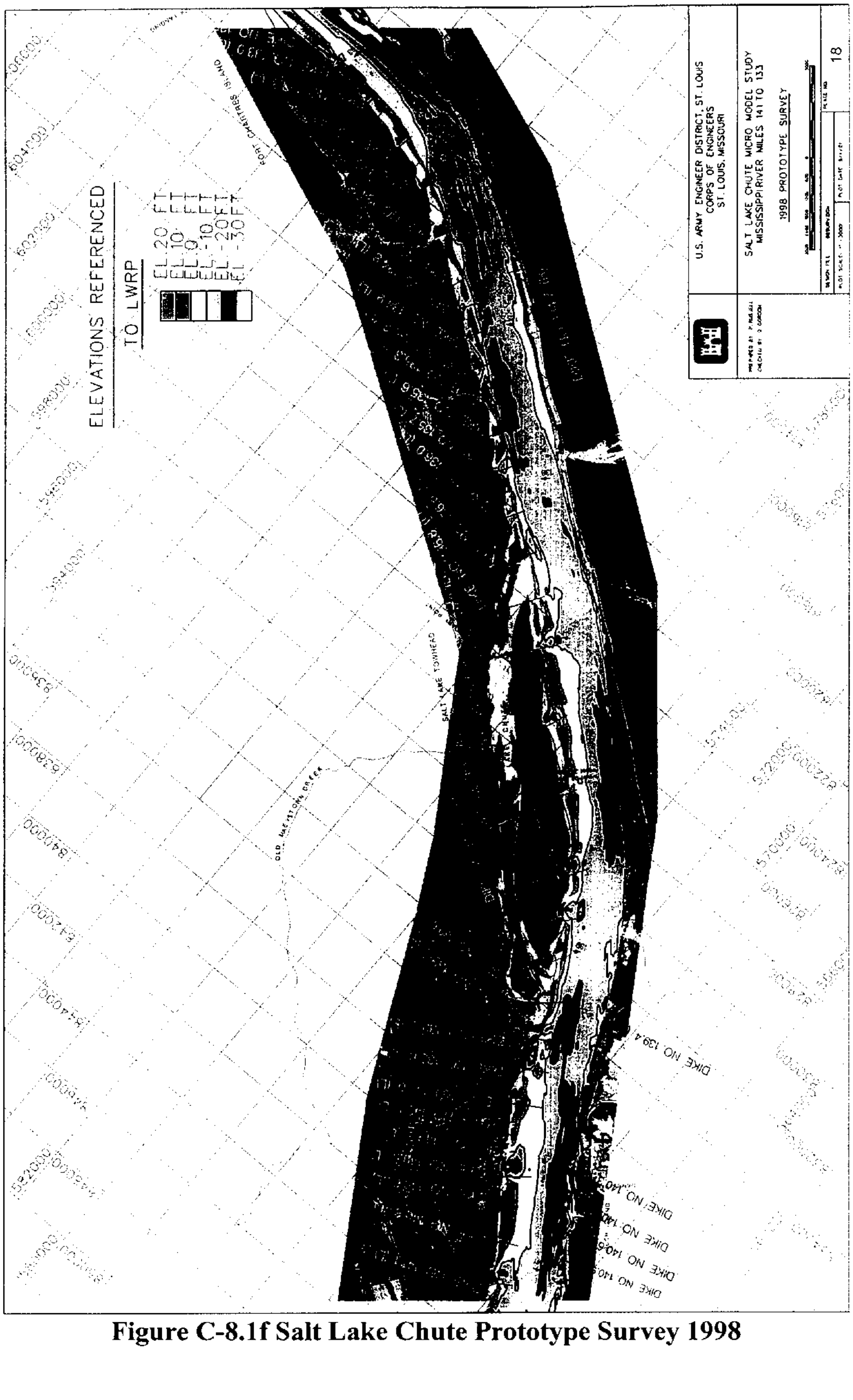

Figure C-8.1f Salt Lake Chute Prototype Survey 1998

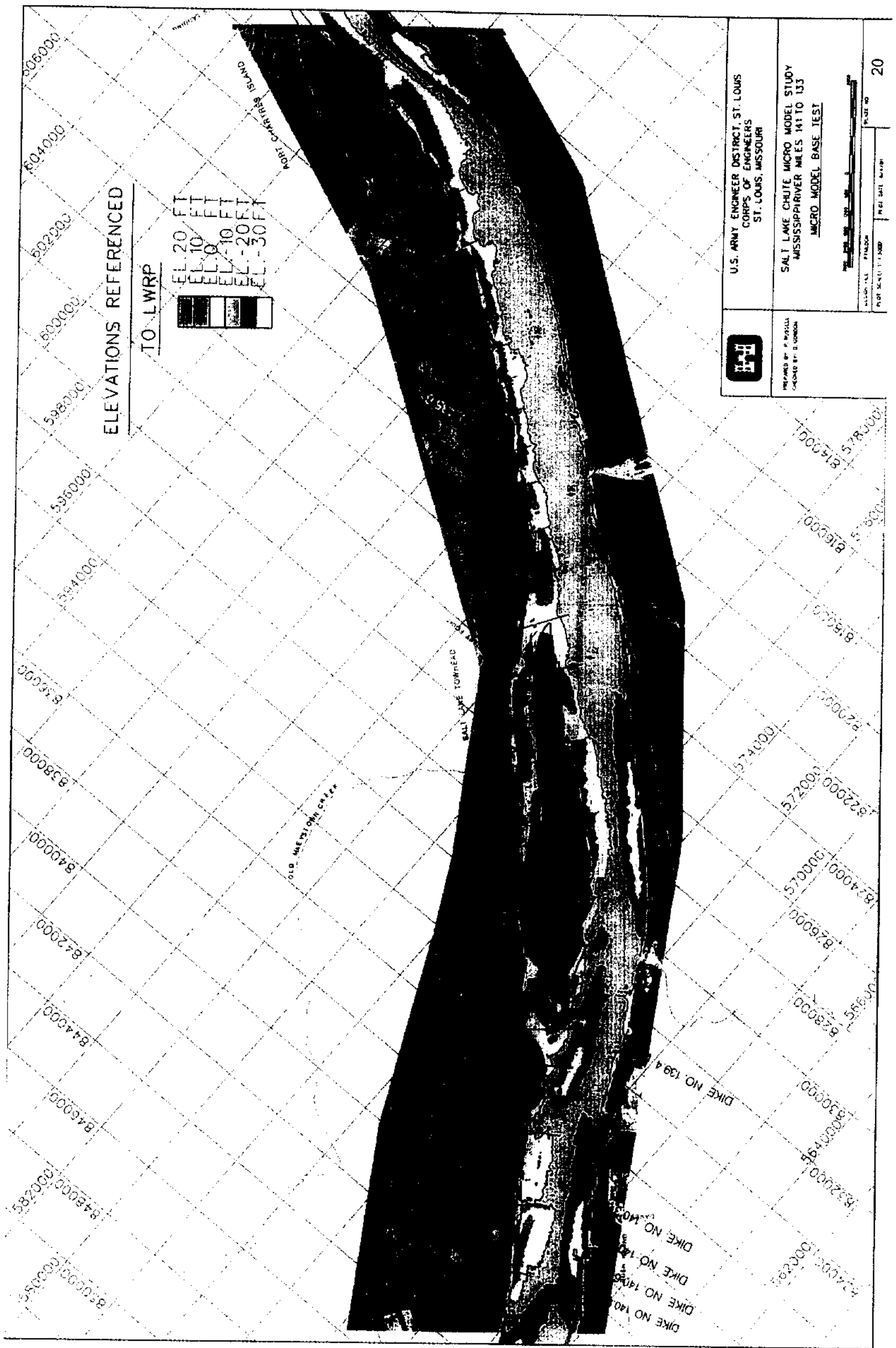

Figure C-8.1g Salt Lake Chute Micromodel Base Test

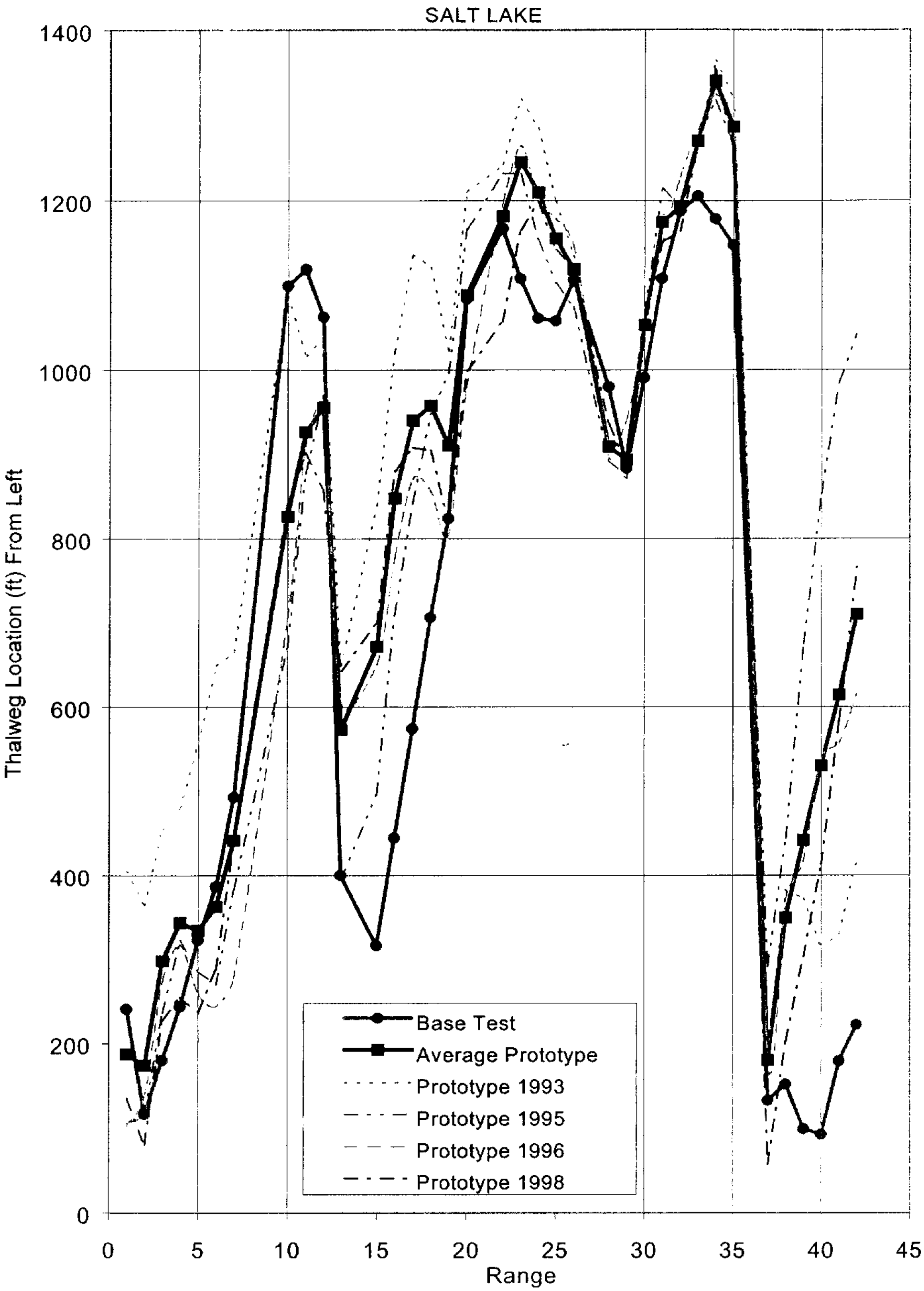

Figure C-8.2a Thalweg Position From Left by Range, Salt Lake Chute (Mississippi River)

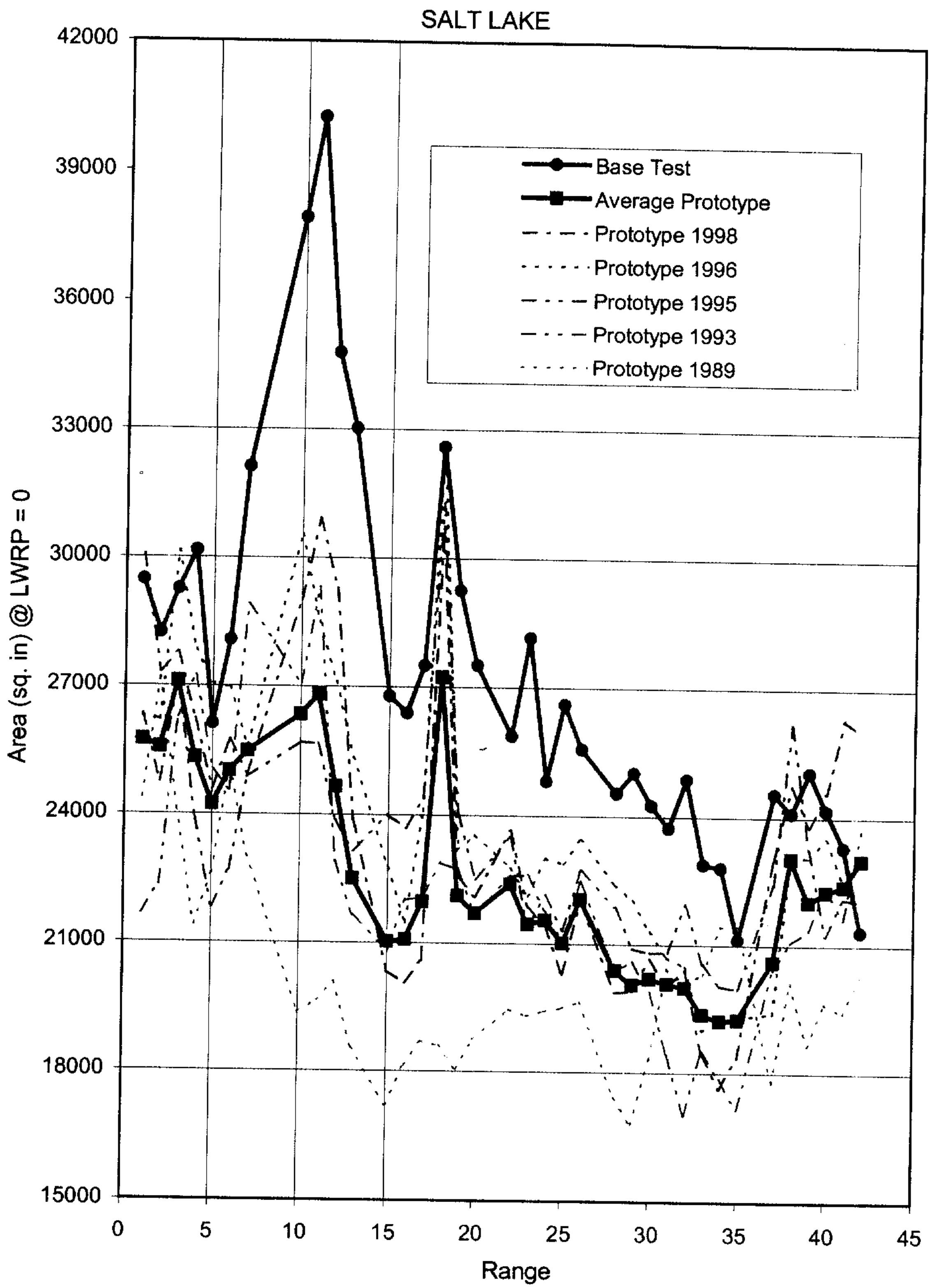

Figure C-8.2b Cross-Section Area by Range, Salt Lake Chute (Mississippi River)

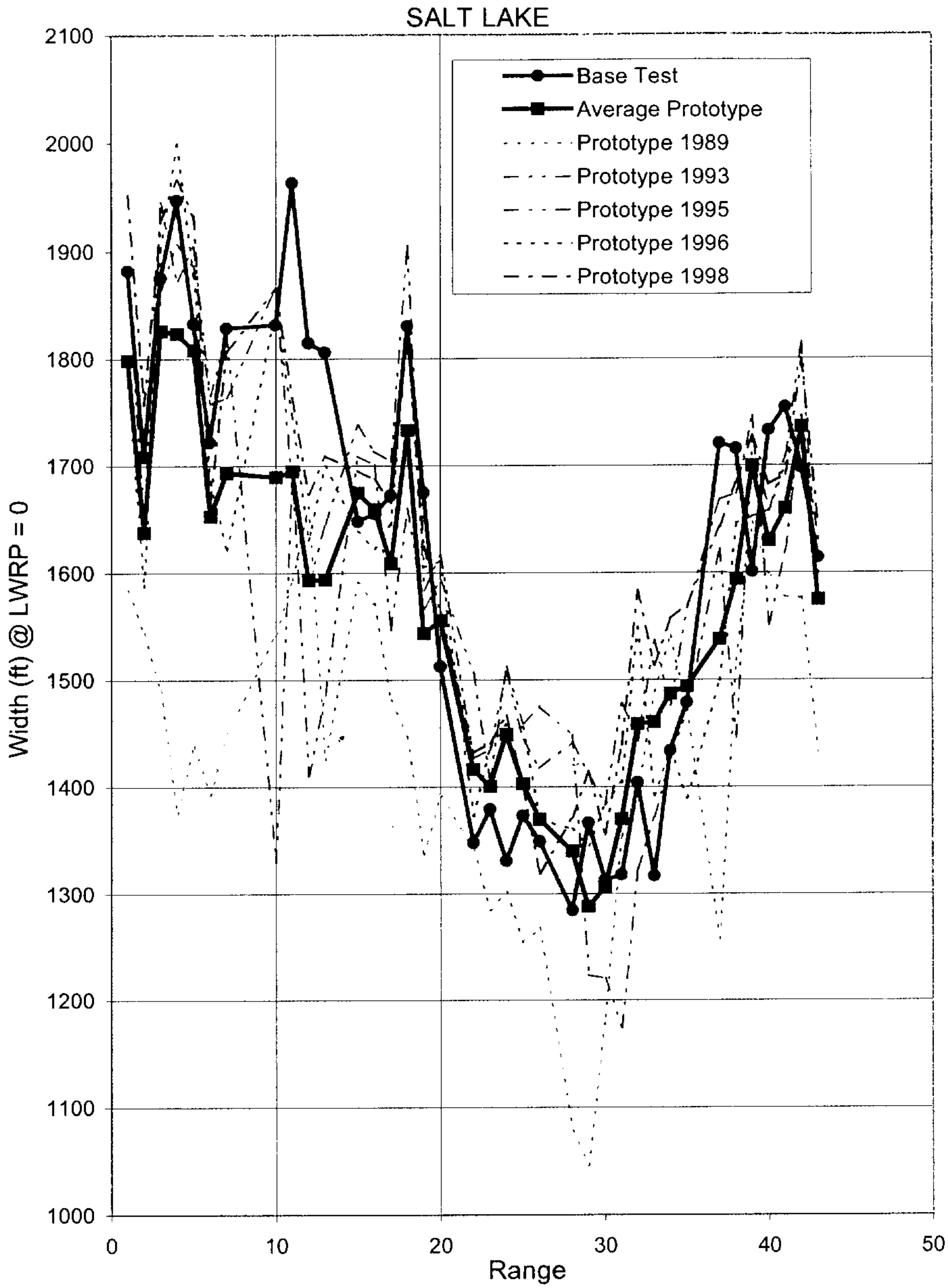

Figure C-8.2c Top Width by Range, Salt Lake Chute (Mississippi River)

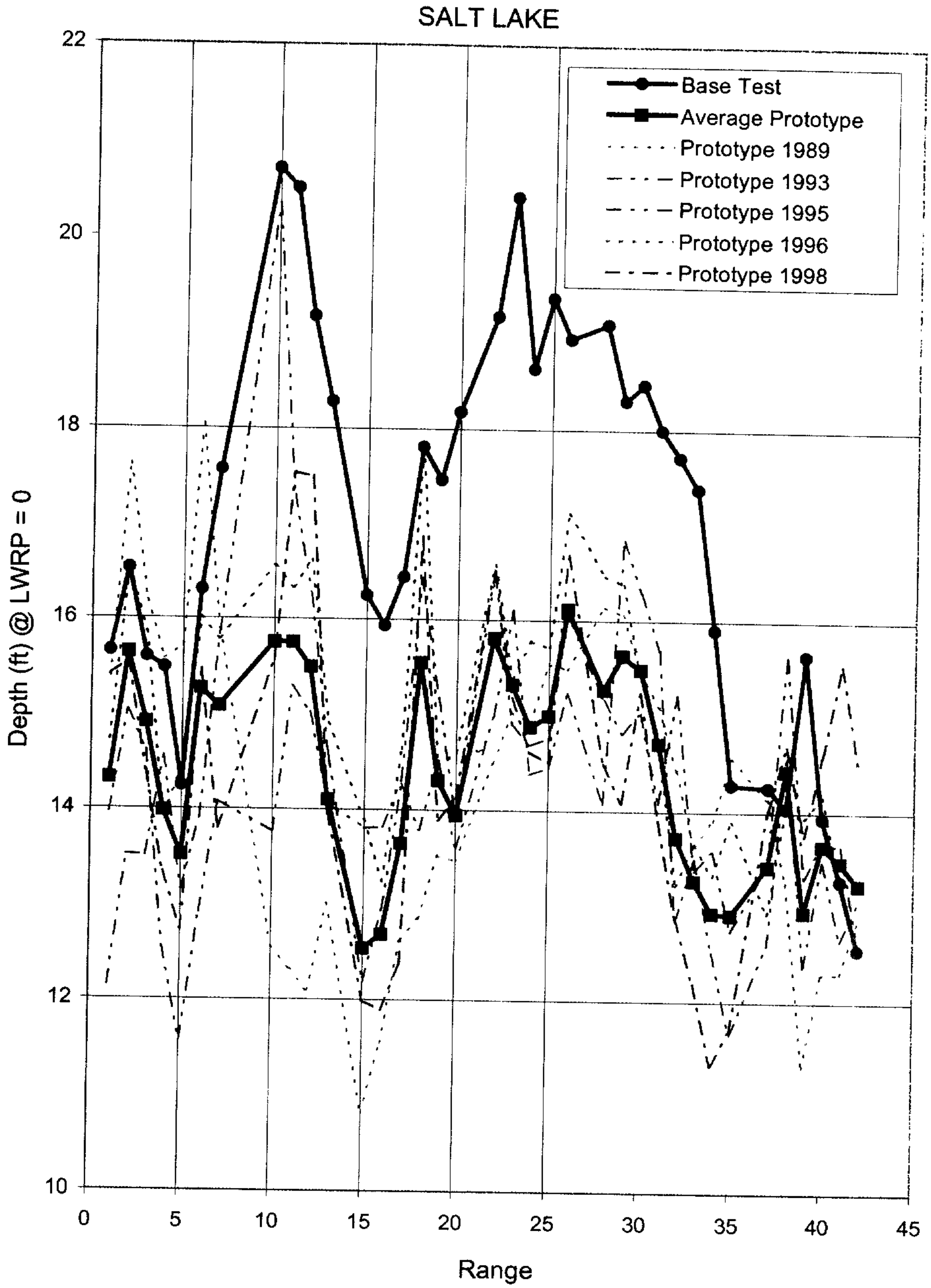

Figure C-8.2d Hydraulic Depth by Range, Salt Lake Chute (Mississippi River)

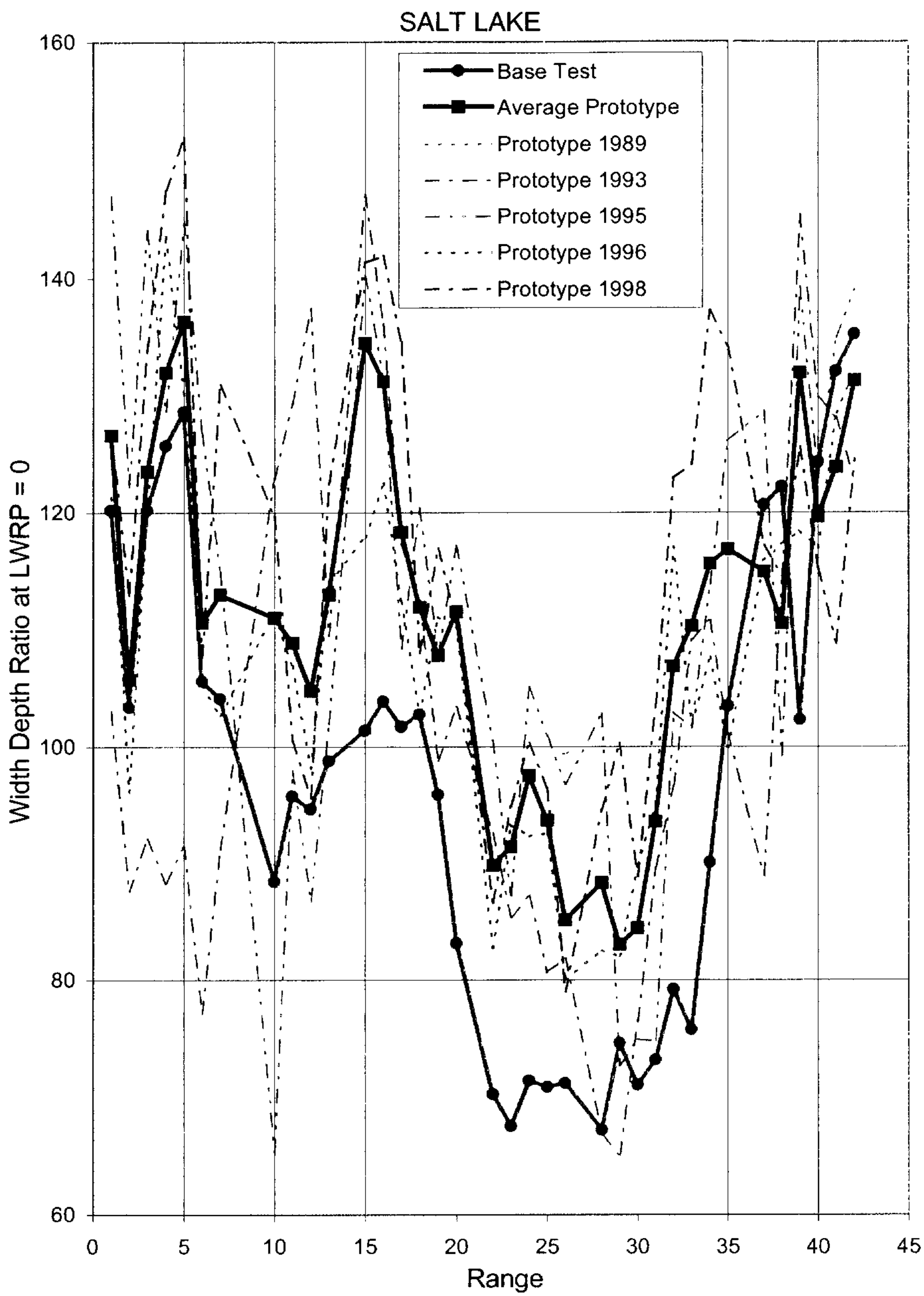

Figure C-8.2e Width/Depth Ratio by Range, Salt Lake Chute (Mississippi River)

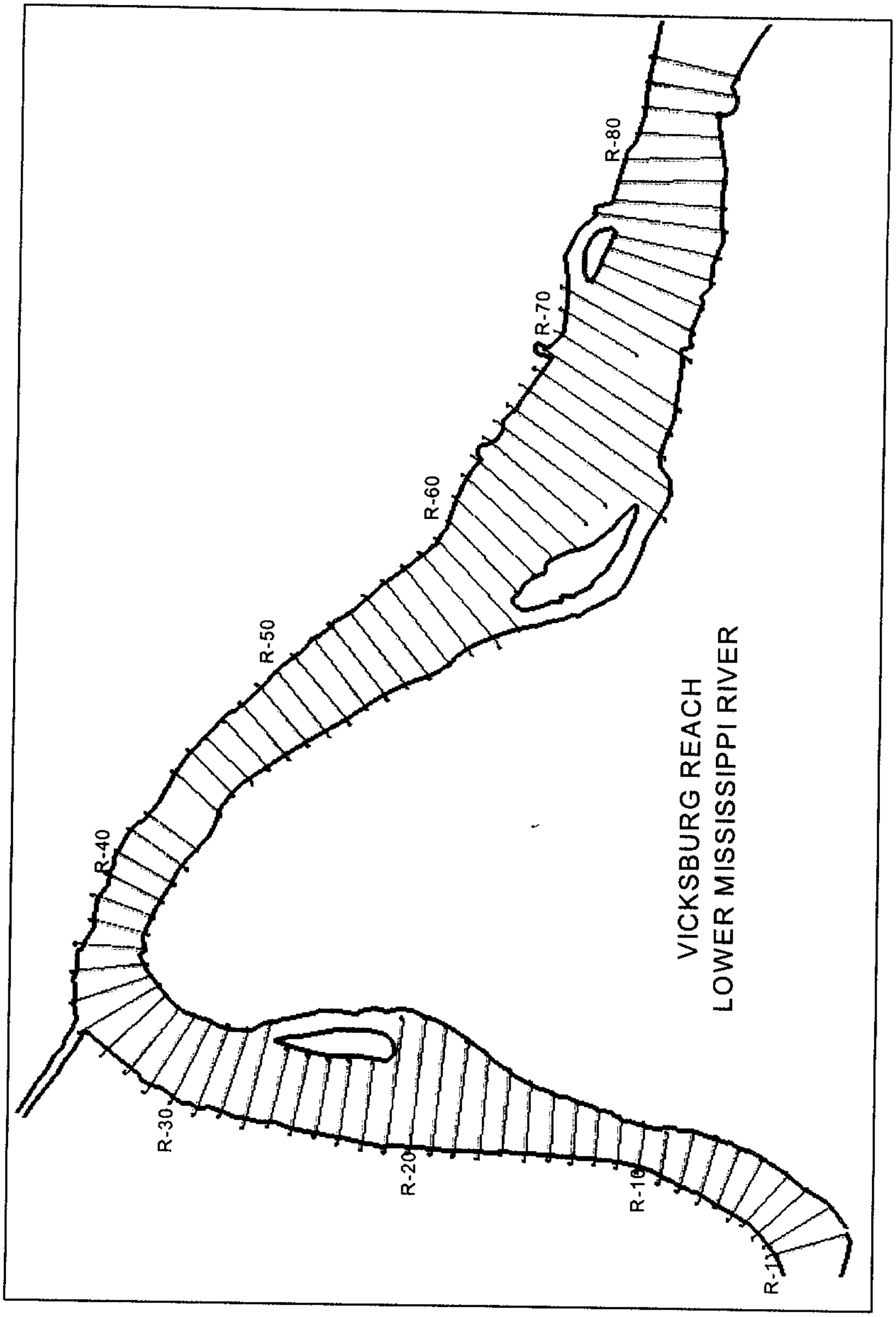

Figure C-9.1a Vicksburg Front Micromodel Plan View

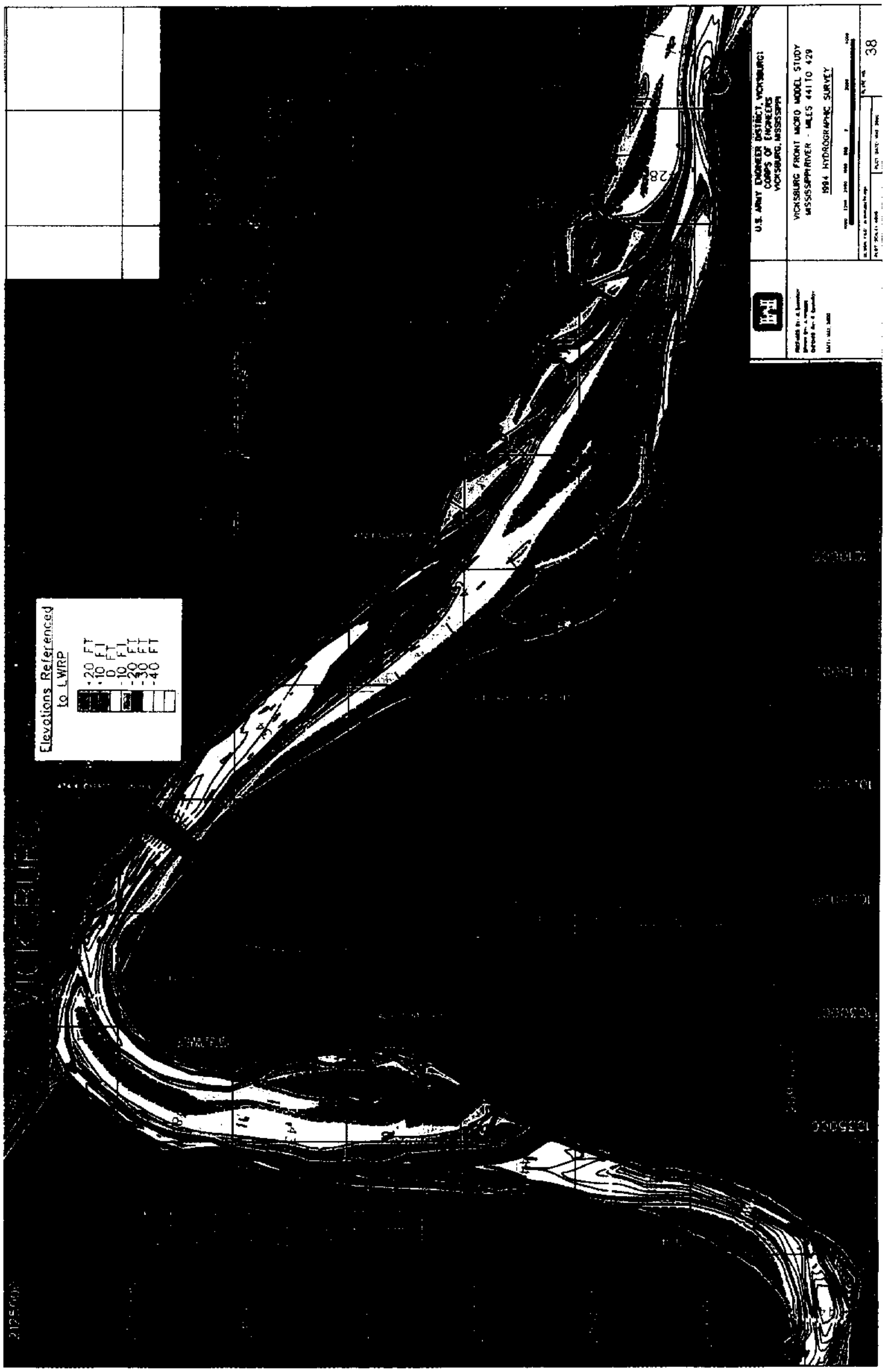

Figure C-9.1b Vicksburg Front Prototype Survey 1994

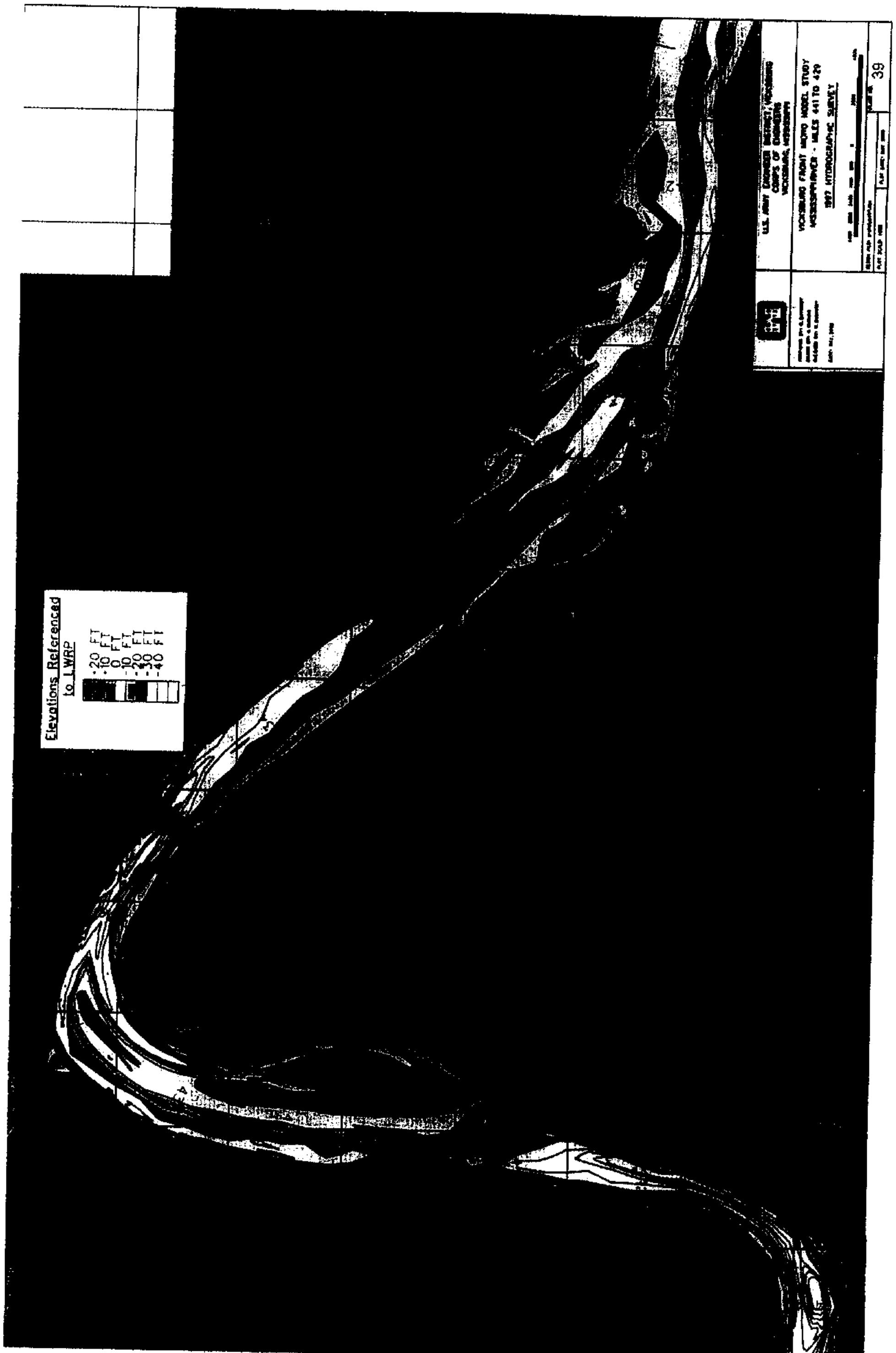

Figure C-9.1c Vicksburg Front Prototype Survey 1997

Figure C-9.1d Vicksburg Front Micromodel Base Test

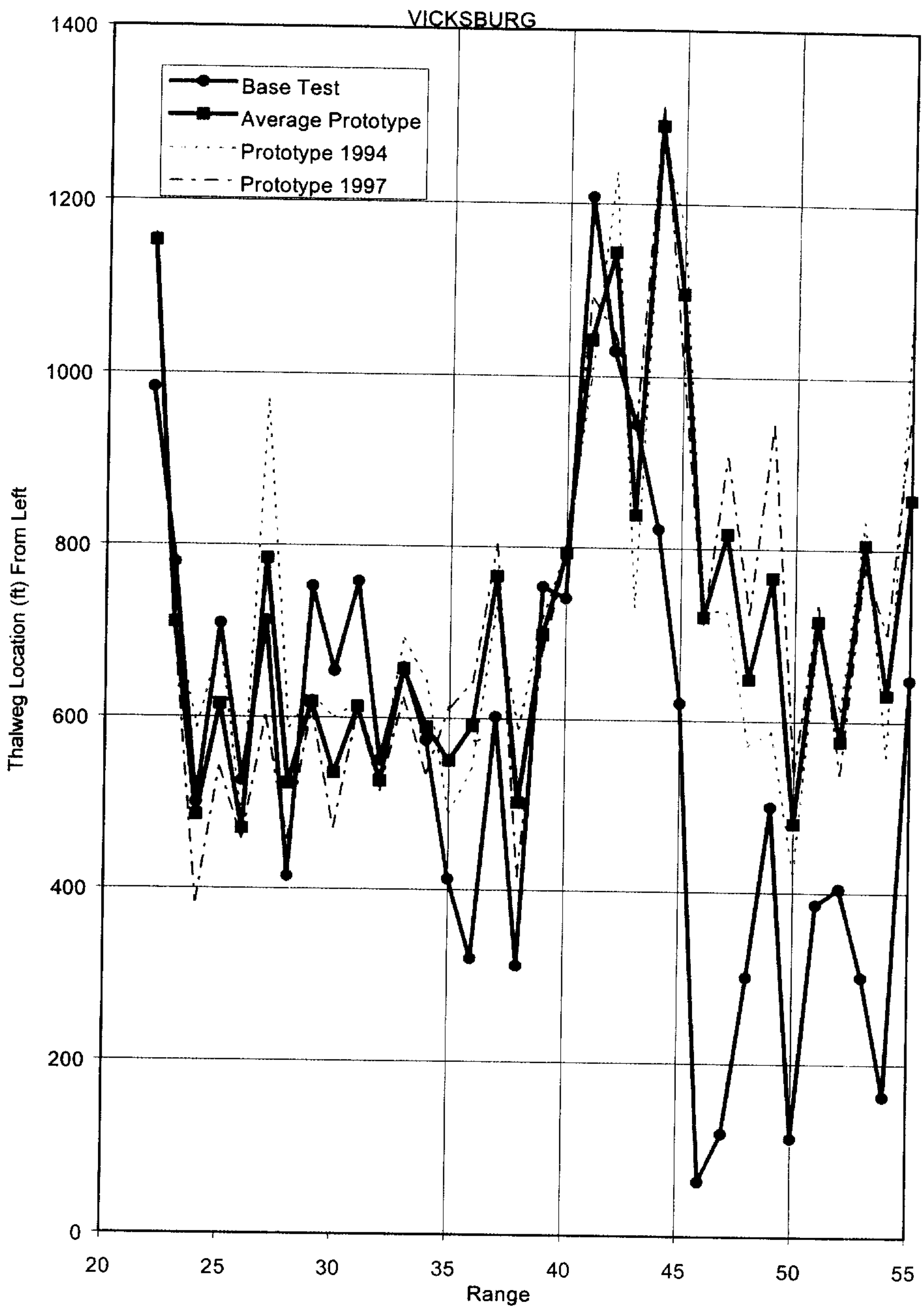

Figure C-9.2a Thalweg Position From Left by Range, Vicksburg Front (Mississippi River)

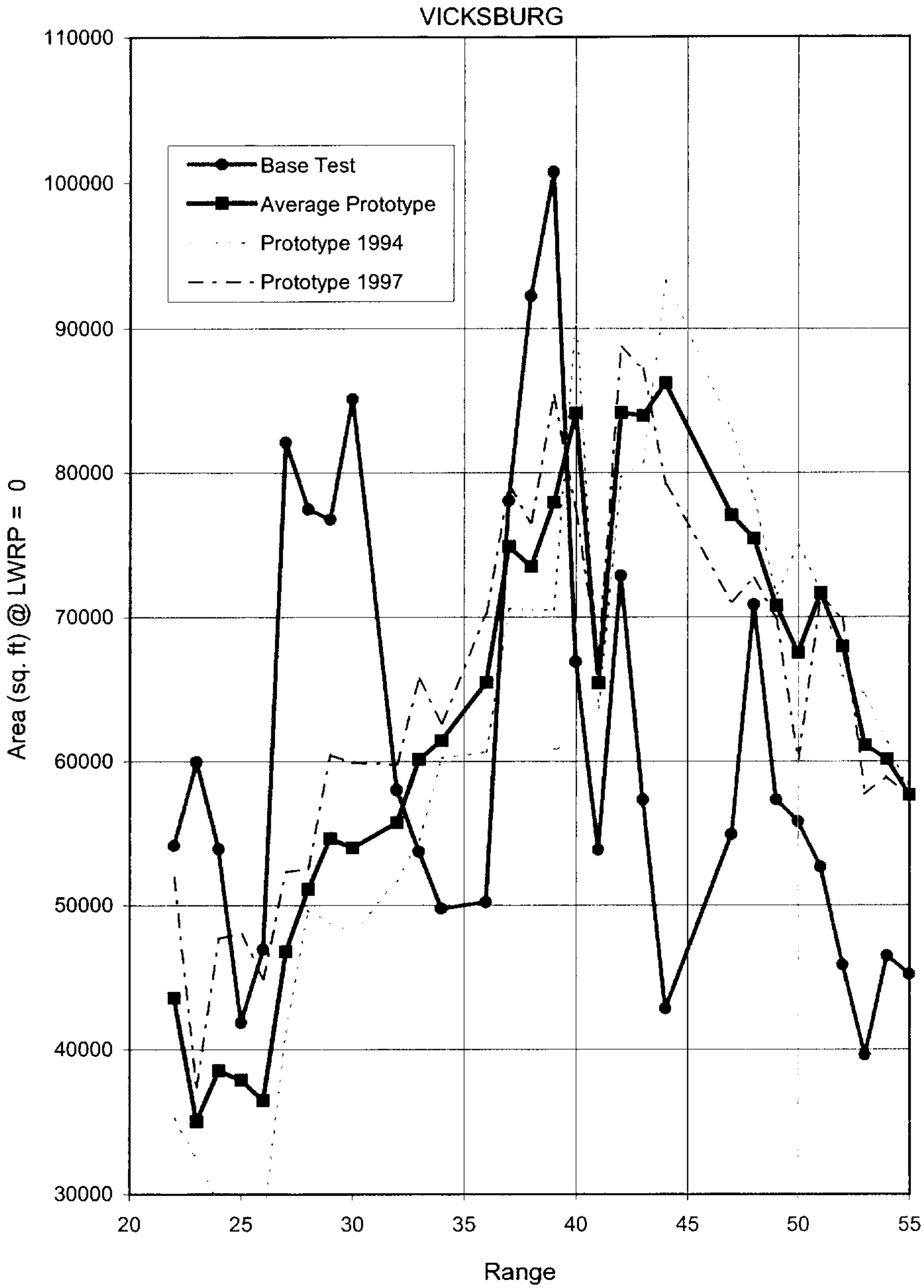

Figure C-9.2b Cross-Section Area by Range, Vicksburg Front (Mississippi River)

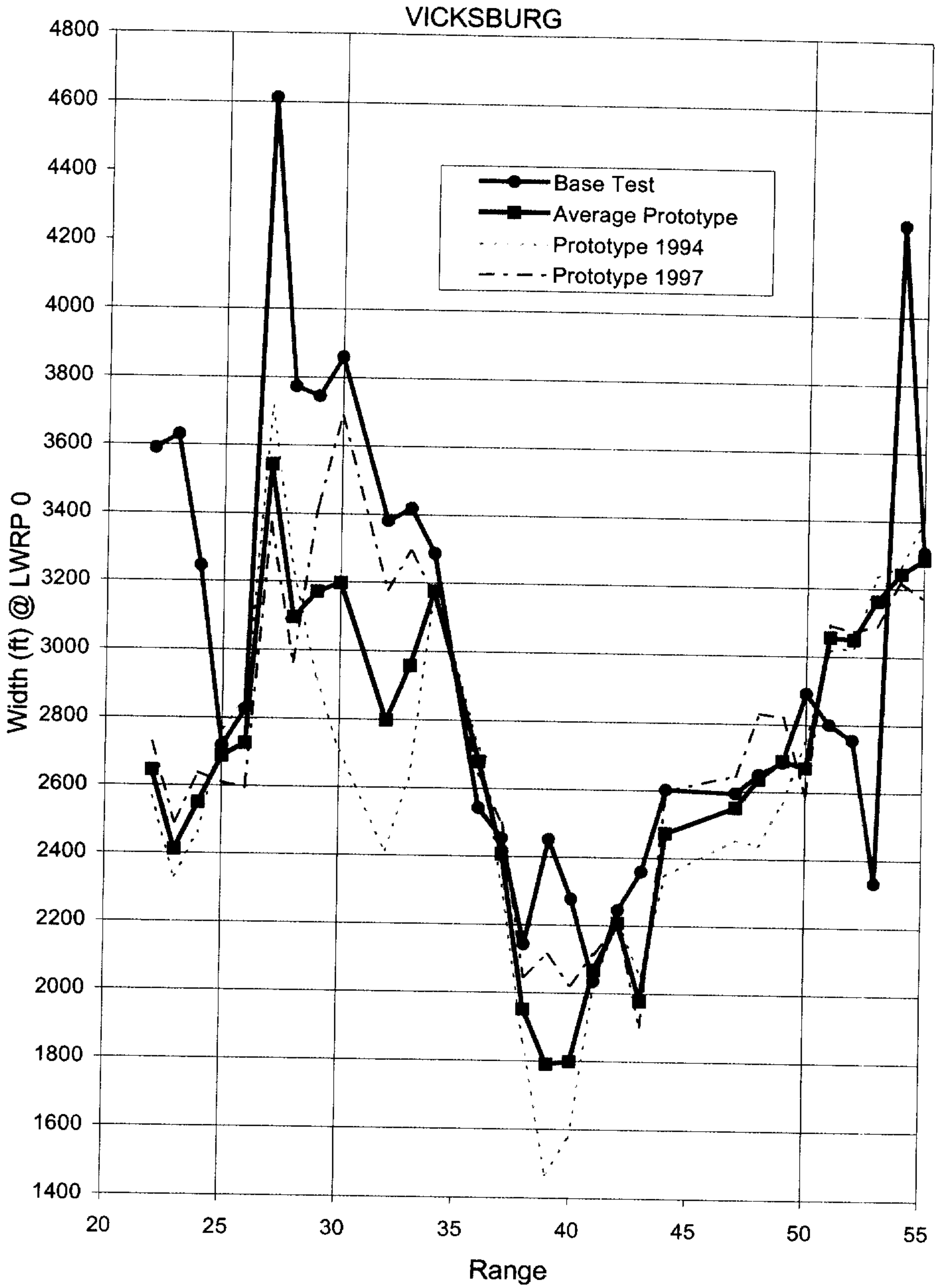

Figure C-9.2c Top Width by Range, Vicksburg Front (Mississippi River)

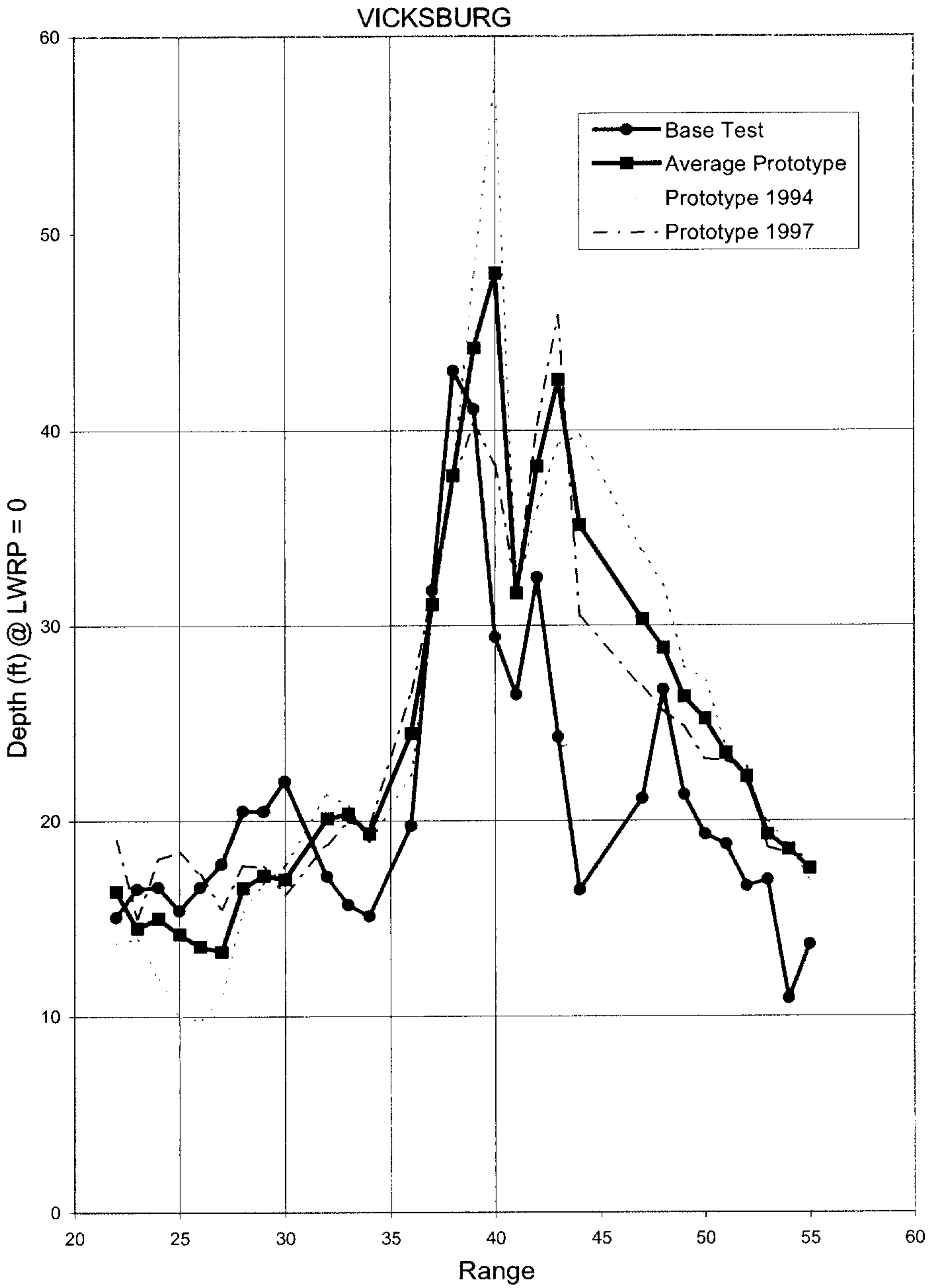

Figure C-9.2d Hydraulic Depth by Range, Vicksburg Front (Mississippi River)

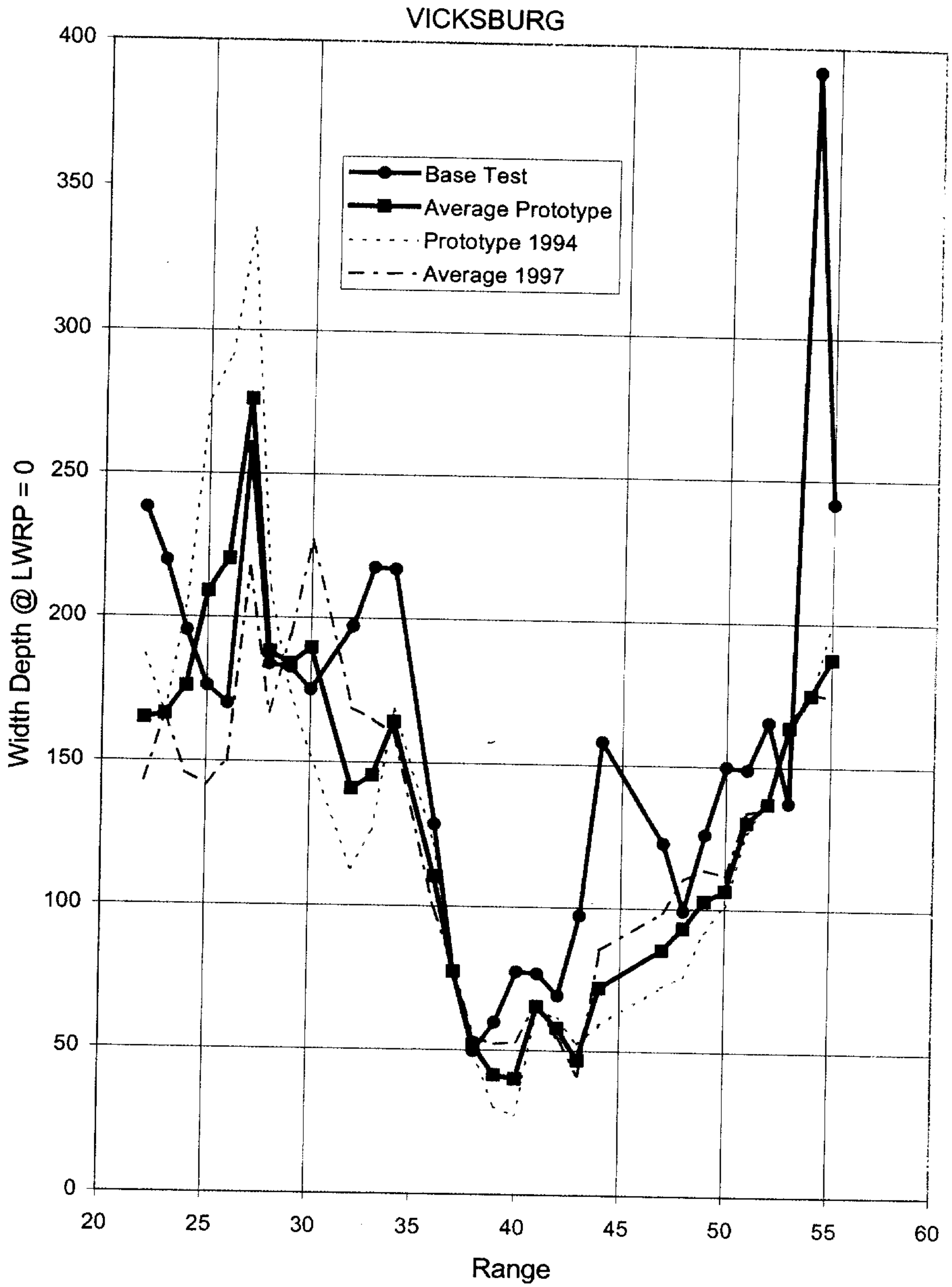

Figure C-9.2e Width/Depth Ratio by Range, Vicksburg Front (Mississippi River)

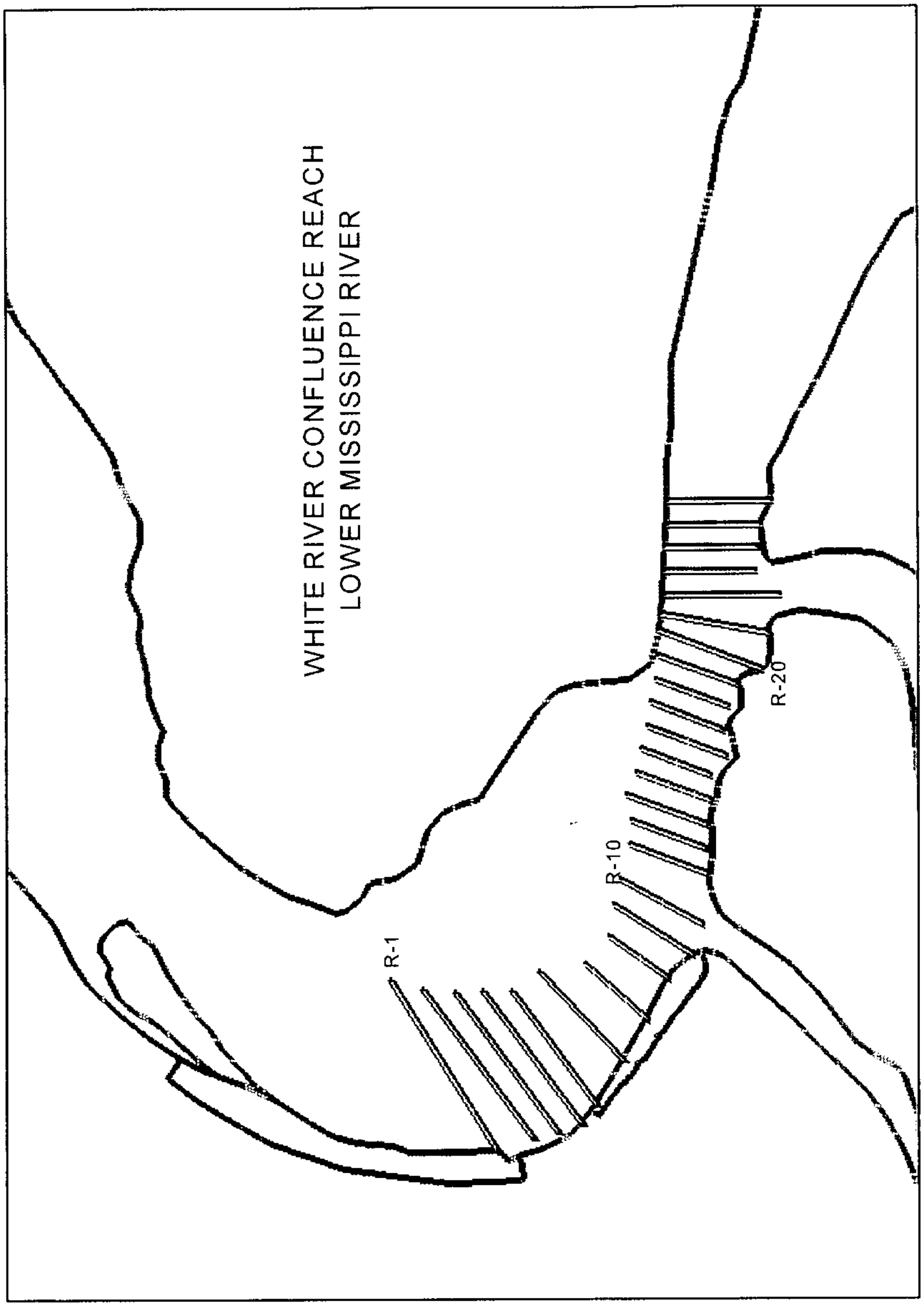

Figure C-10.1a White River Confluence with Mississippi River Micromodel Plan View

Figure C-10.1b White River Confluence with Mississippi River Prototype Survey 1994

Figure C-10.1c White River Confluence with Mississippi River Prototype Survey 1997

Figure C-10.1d White River Confluence with Mississippi River Micromodel Base Test

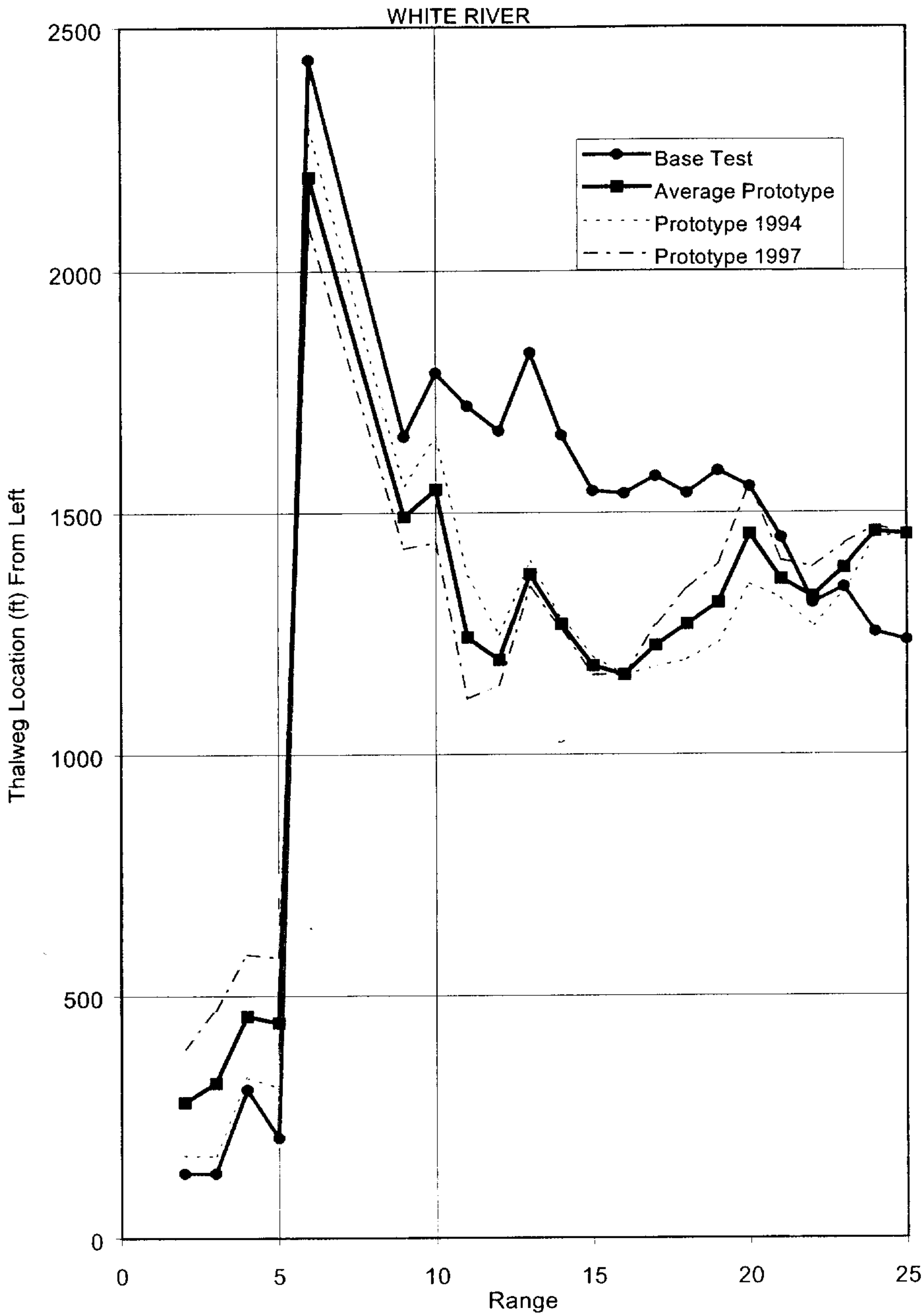

Figure C-10.2a Thalweg Distance From Left by Range, White River Confluence with Mississippi River

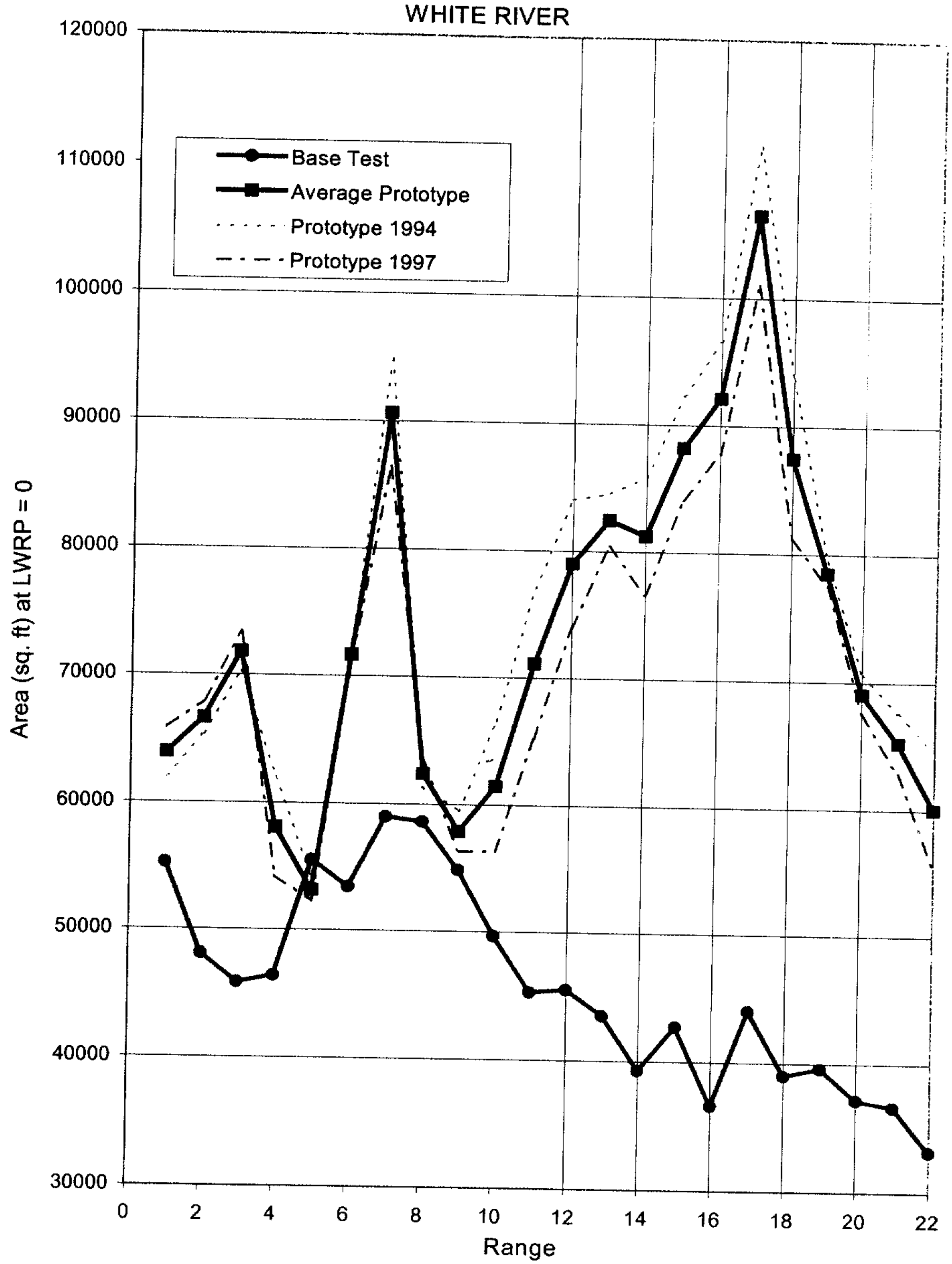

Figure C-10.2b Cross-Section Area by Range, White River Confluence with Mississippi River

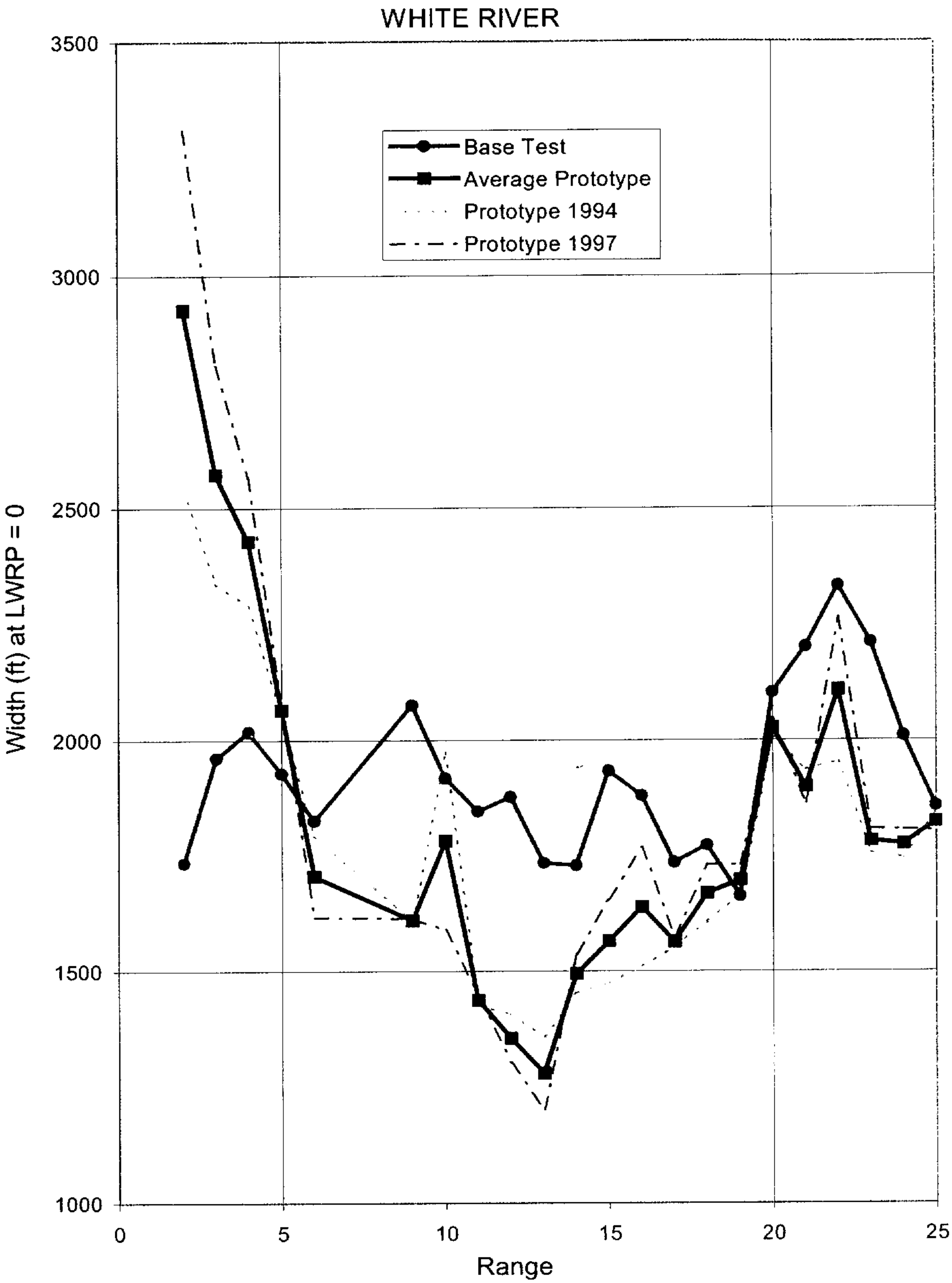

Figure C-10.2c Top Width by Range, White River Confluence with Mississippi River

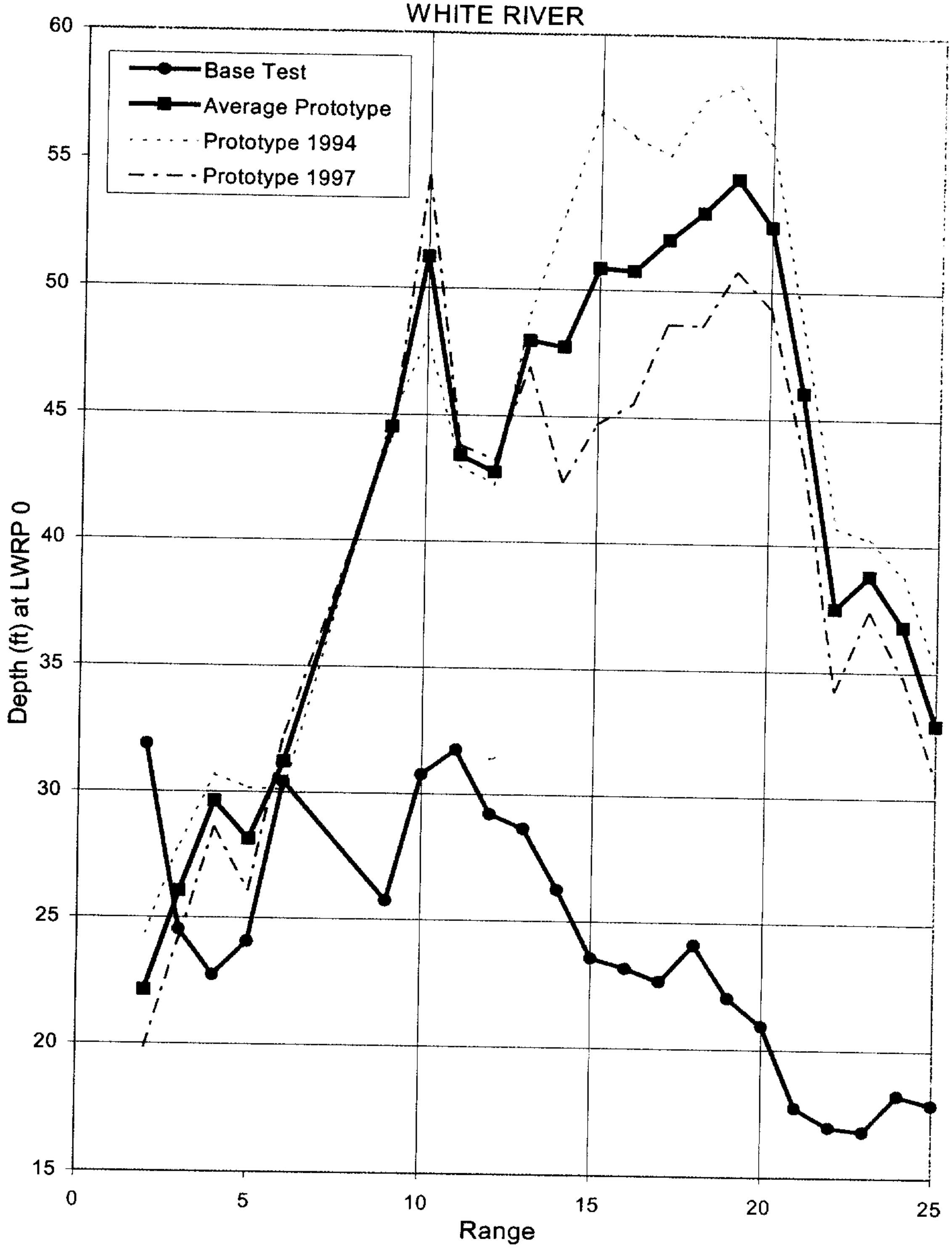

Figure C-10.2d Hydraulic Depth by Range, White River Confluence with Mississippi River

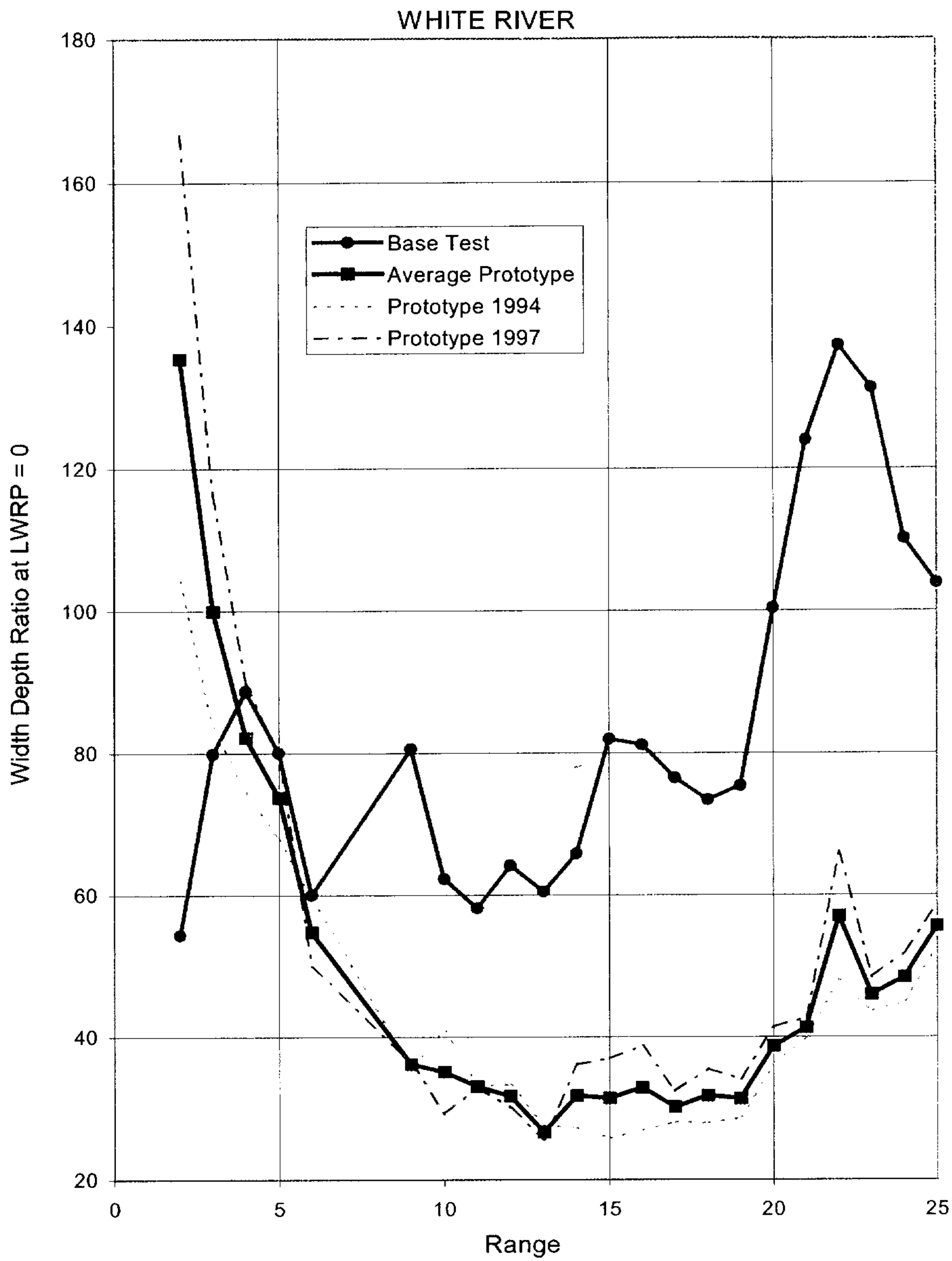

Figure C-10.2e Width/Depth Ratio by Range, White River Confluence with Mississippi River

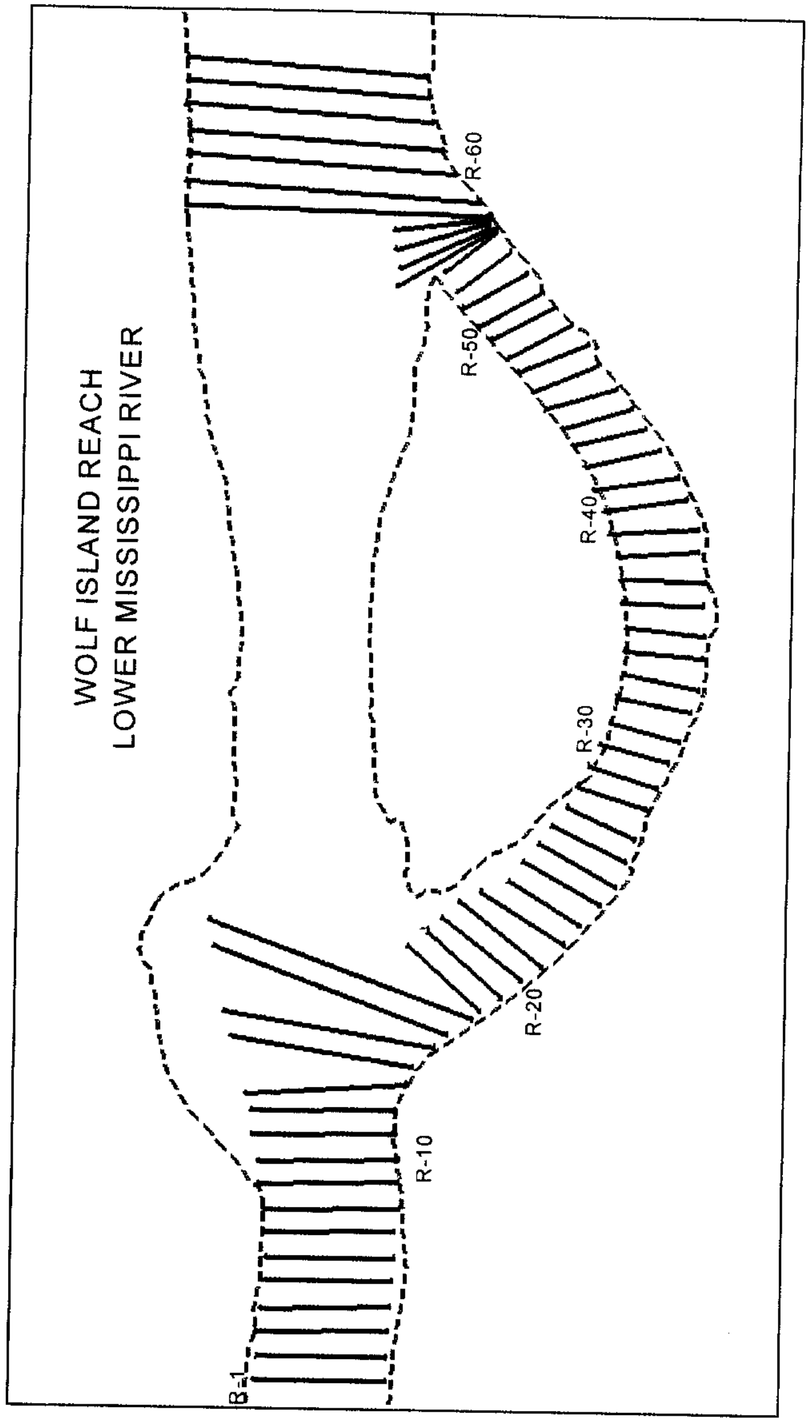

Figure C-11.1a Wolf Island Micromodel Plan View

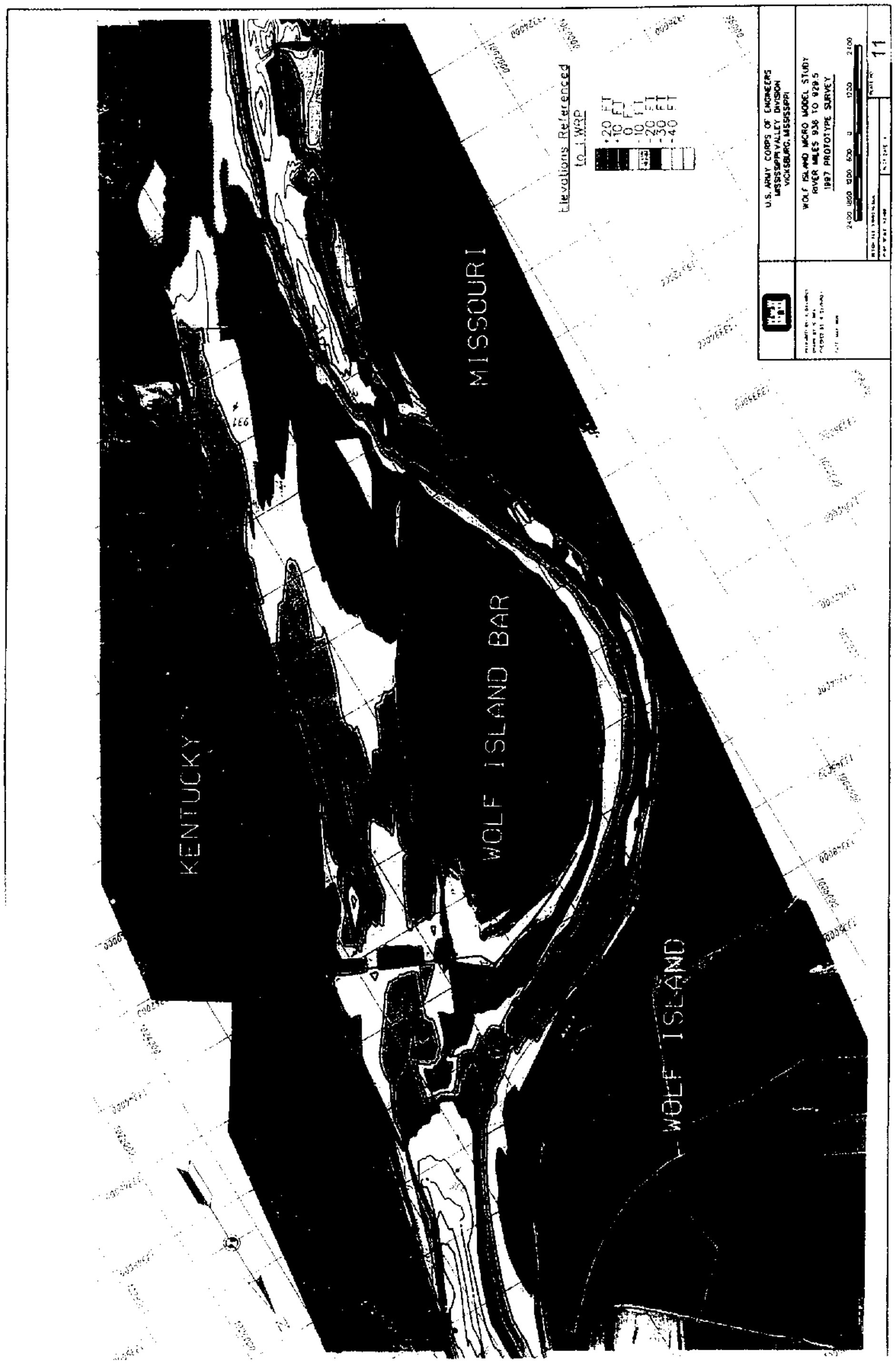

Figure C-11.1b Wolf Island Prototype Survey 1997

Figure C-11.1c Wolf Island Prototype Survey 1998

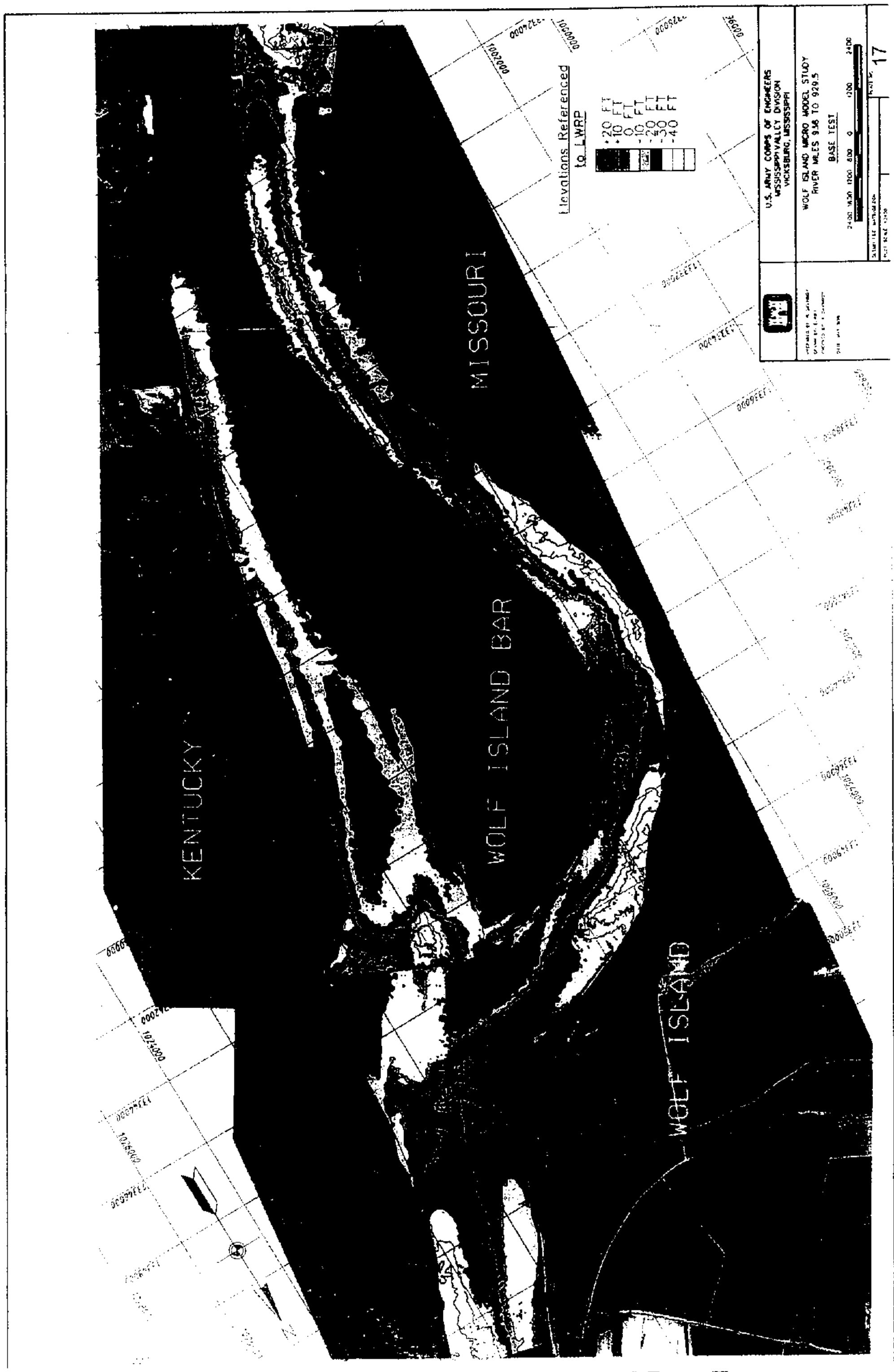

Figure C-11.1d Wolf Island Micromodel Base Test

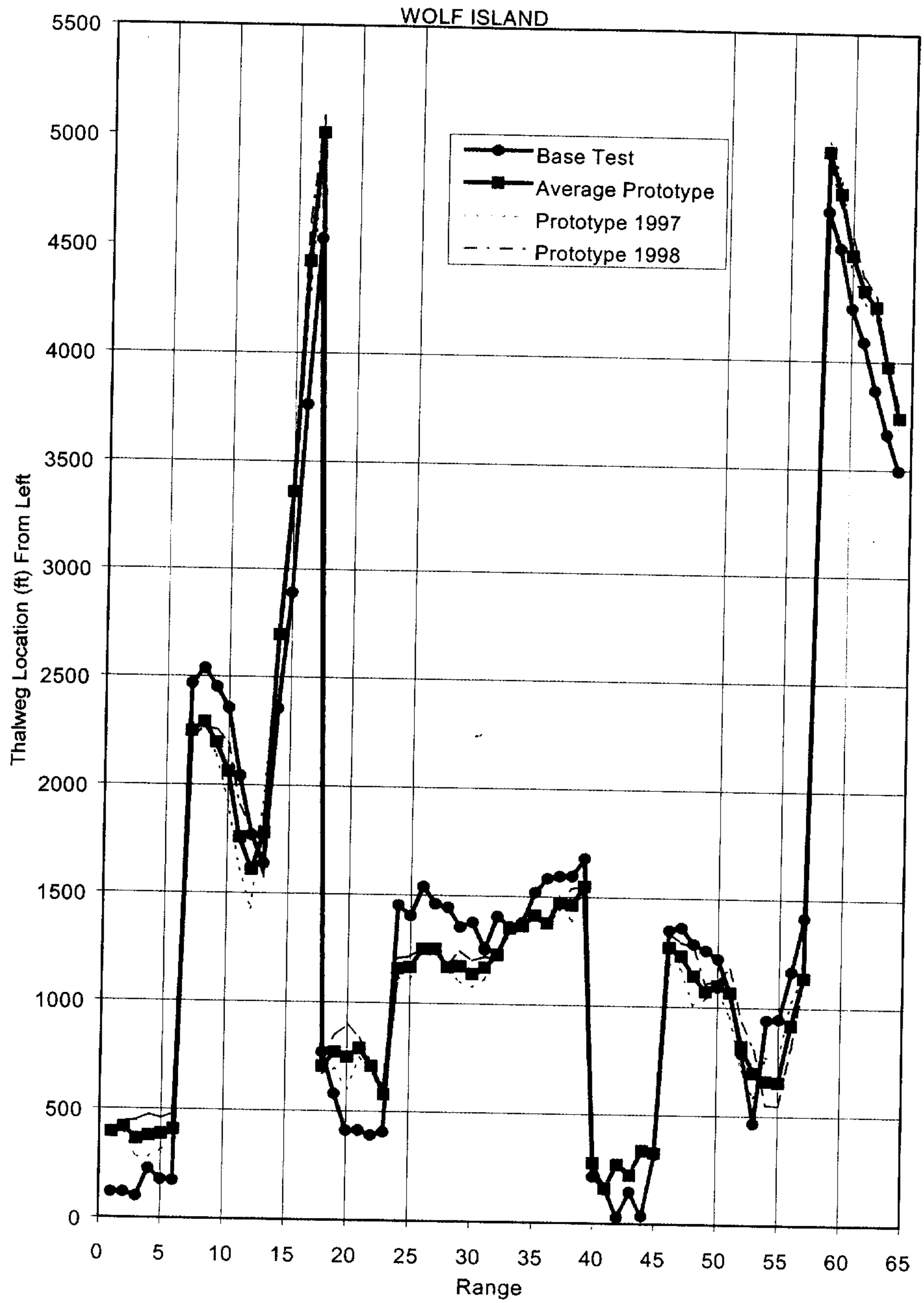

Figure C-11.2a Thalweg Position From Left by Range, Wolf Island (Mississippi River)

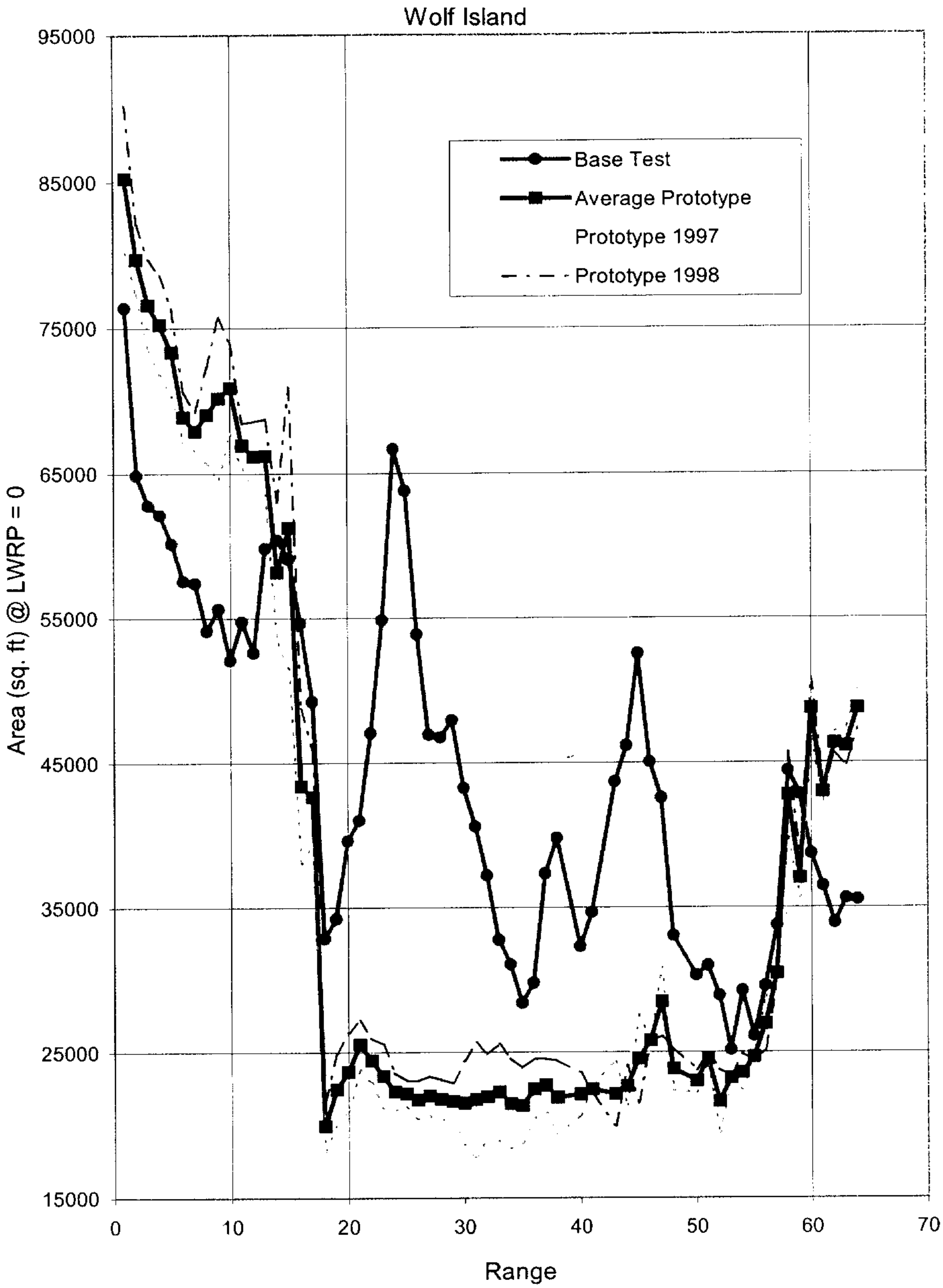

Figure C-11.2b Cross-Section Area by Range, Wolf Island (Mississippi River)

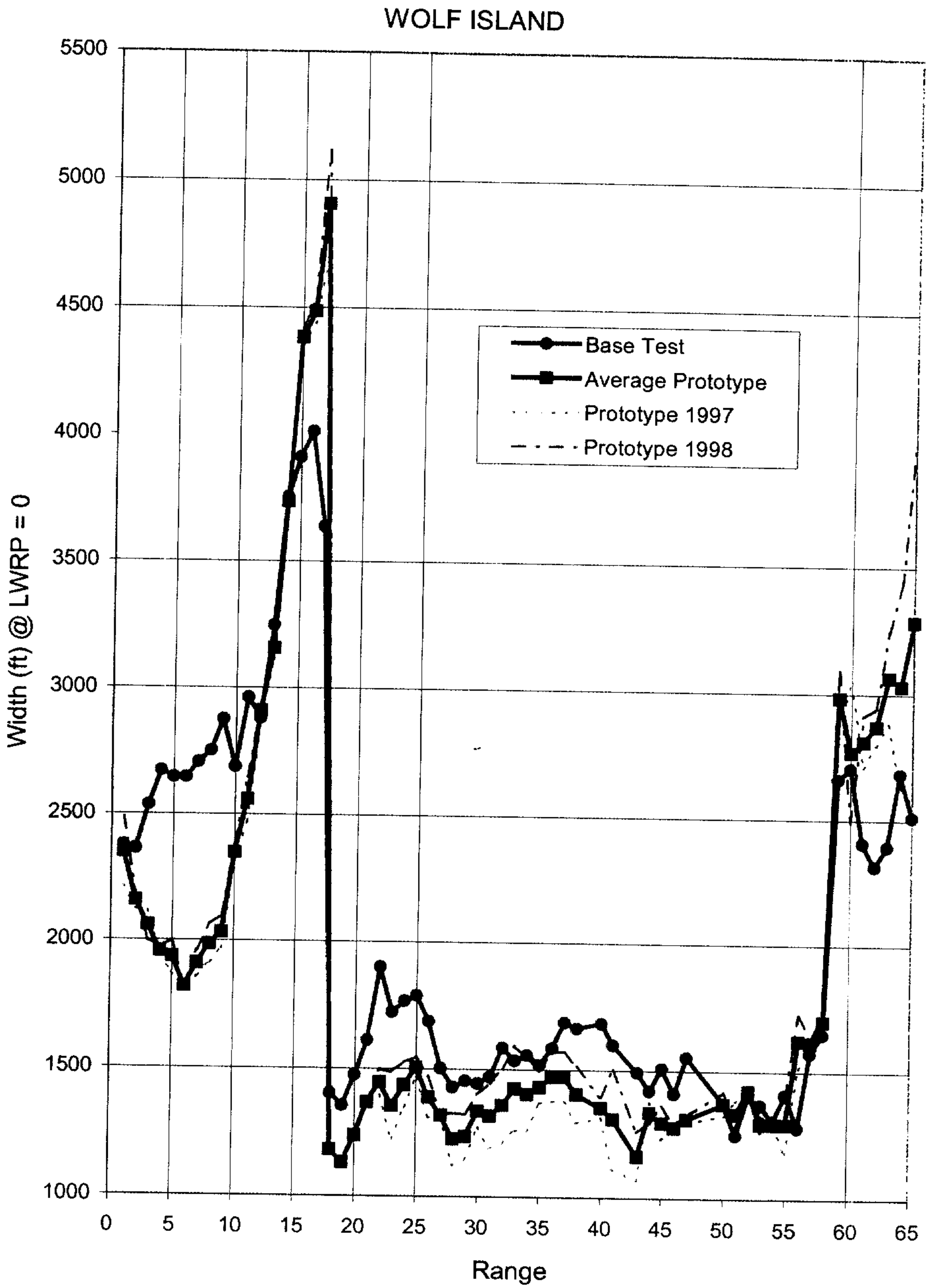

Figure C-11.2c Top Width by Range, Wolf Island (Mississippi River)

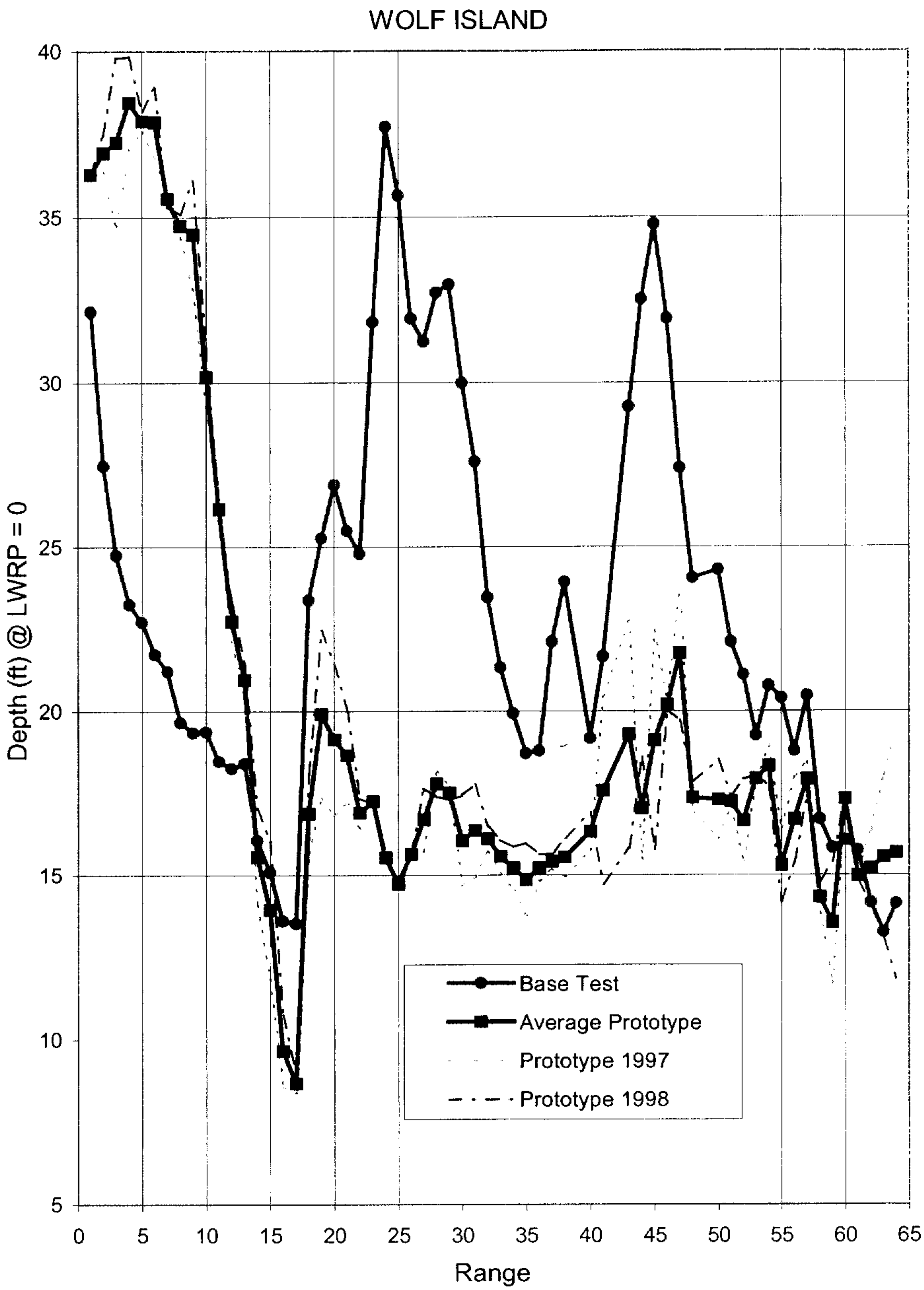

Figure C-11.2d Hydraulic Depth by Range, Wolf Island (Mississippi River)

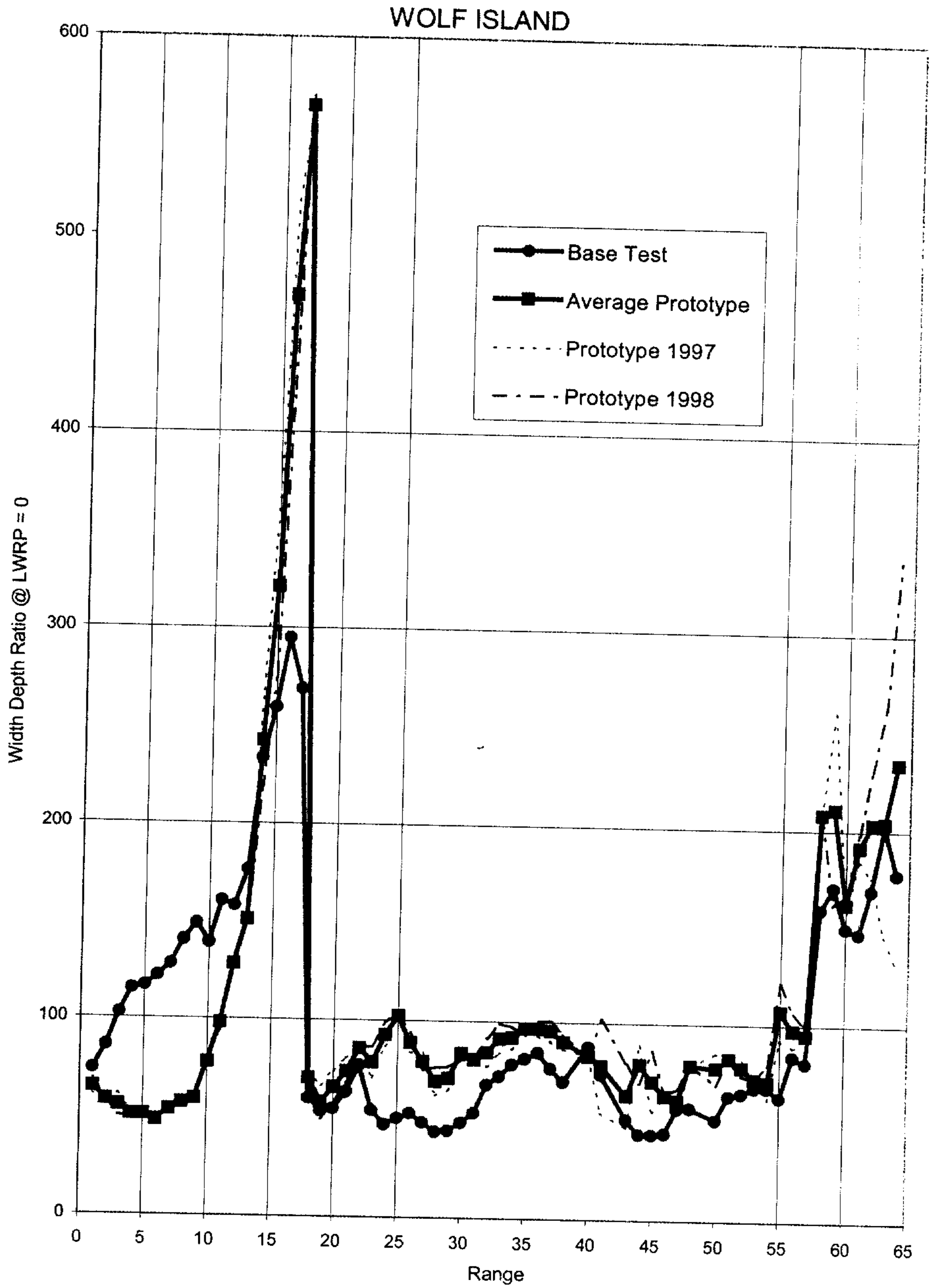

Figure C-11.2e Width/Depth Ratio by Range, Wolf Island (Mississippi River)

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